SPECIFIC EFFECTS OF RATIONS ON THE DEVELOPMENT OF SWINE

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[1]In cooperation with the College of Agriculture, Ohio State University, Columbus.
[2]In cooperation with the U. S. Department of Agriculture.

PREFACE

The feeding experiments on which this bulletin is based were conducted by the author at the Missouri Experiment Station in the years 1905 and 1906, and the results prepared for publication immediately thereafter.

The chemical data are principally the work of Dr. Paul Schweitzer, Dr. R. M. Bird and Mr. F. W. Liepsner, all of whom were connected with the Missouri Station at the time the work was done. The author acknowledges with much gratitude his indebtedness to these chemists, and also to Dr. C. W. Greene and Dr. W. Koch for courtesies enjoyed in their laboratories.

Certain additions to the chemical data are now made from the work of Mr. A. C. Whittier and the author, at the Ohio Experiment Station; the discussion is revised, and the bulletin is published at the Ohio Experiment Station, and issued simultaneously by the Missouri and Ohio stations.

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// BULLETIN

OF THE

Ohio Agricultural Experiment Station

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SPECIFIC EFFECTS OF RATIONS ON THE DEVELOPMENT OF SWINE

By E. B. FORBES

INTRODUCTION

The characters of growing animals are determined by the limitations imposed by inheritance and the food supply. Inheritance furnishes detailed plans and specifications; food builds and maintains the structure.

Deficiences in the amount and kinds of nutriment available may affect not only the size, but also, within limits, the character of the growth of animals, just as shortage of certain building materials would affect the size and style of construction of a building.

The animal body is constructed from fourteen chemical elements. Not all foods contain all of these substances in amounts sufficient to sustain growth. Many of our by-product foods are abnormal and require knowledge and judgment in their use for animals; and Indian corn is, in a number of ways, deficient as a food for growing animals.

In the hands of stock breeders corn proves to be a poor producer of bone and muscle, and animals fed too little else along with their corn are apt to be lacking in size. The professional herdsman, and also many of the successful breeders of pure-bred stock of all kinds, believe that corn is injurious to breeding animals. We believe, however, that there is no time in the life of any farm animal in the Corn Belt when corn may not properly be used, whether it be with a fast horse or a slow one, a milch cow or a bacon hog, a laying hen or a breeding ewe; but for many purposes it must be used in moderation, and must be properly supplemented, so as to provide those nutrients in which it is deficient. Animals need energy-producing food, much more of it than of any other sort, and in this region corn will supply this kind of nutriment more cheaply than will any other food.

The specific effects of foods on growing animals appear to be due very largely to the mineral elements which they contain.[1]

The influence of these constituents on the relative development of fat, bone, muscle and visceral organs and on the qualitative composition of these tissues is, however, practically an unworked field, and appears to give promise of yielding much valuable information.

When the live-stock feeder shall have become thoroughly a master of his business, he will know the specific or characteristic effects of the foodstuffs which he uses, on the animals consuming them, just as the physician who is learned in therapeutics knows the specific actions of the drugs which he administers.

The fact that foodstuffs do have these specific effects on animals was demonstrated many years ago by J. W. Sanborn[2] of the Missouri Agricultural College. Subsequent work by Henry[3], and Shelton[4], along this same line confirmed Sanborn's conclusion, that rations containing more protein than does Indian corn produce more muscular growth. These writers, however, made no mention of the mineral constituents of the foodstuffs used.

In compounding the rations fed in these various experiments, these authors apparently sought only to vary the proportions of the nitrogenous and non-nitrogenous organic nutrients without reference to mineral or ash constituents. It is true, however, that in these rations the nitrogenous and mineral constituents varied together so that the high-protein rations happened also to be high in ash constituents; hence there is hardly warrant for assuming that the proteid compounds alone are responsible for the effects observed on the relative development of fat and muscular tissue.

This above-mentioned work has been quantitative only, in so far as the various tissues are concerned, except in that Henry, Shelton, Carlyle[5] and Burnett[6], have observed the fact that the ash constituents of foodstuffs profoundly affect the ash content and breaking strength of the bones of hogs consuming them.

Numerous investigations, especially those of Shutt of Canada, have also proven that the fat of hogs is susceptible of chemical modification through the use of ordinary foodstuffs.

In considering the significance of variations in the size of organs, and the development of tissues, one should bear in mind that all of the so-called vital organs together, including the nervous system, contain very much less substance than the remaining less essential

[1] See Ohio Bul. 201, page 132.
[2] Bul. 10, 14, 19, Missouri Agricultural College.
[3] Annual Reports, Wis. Agr. Exp. Sta., 1886, '87, '88, '89.
[4] Bul. 9, Kans. Agr. Exp. Sta.
[5] Bul. 104, Wis. Agr. Exp. Sta.
[6] Bul. 94, 107, Neb. Agr. Exp. Sta.

parts; and rations which are so abnormal as to be inadequate to the necessities of these vital organs are very much more rare in practice than rations which would not contain sufficient nutriment, in excess of the demands of the vital organs, to support maximum development of the less essential parts. Hence it is especially in the development of the less essential fat, bones and muscles that we find the more noticeable specific effects of rations rather than in the development of the vital parts. These more important and carefully guarded vital organs are, of course, dependent in the end on the food supply just as are the less important ones which may serve them as stores of nutriment, and in especially compounded rations we have been able, in experiments at the Ohio Station, to modify even the chemical composition of the brain by withholding from the animal, phosphorus in the particular condition required by this organ.

These and other vital organs are maintained in condition to do their work, whether there be nutriment enough to support maximum development of the less essential organs or not; in fact, the wellbeing of the more important organs is maintained at the expense of the less important whenever insufficiency of nutrients makes this necessary. Thus fatty tissue is of less functional value to the animal than most others, and hence is sacrificed whenever the maintenance of more important tissues requires it. Muscular tissue also may be used up to such extent that the animal becomes much emaciated, in the maintenance of more important tissues in condition to perform their work.

The maintenance of the neutrality of the blood and tissues is of greater importance than the growth of the bones, and hence we find bony substance sacrificed whenever its carbonates are needed to neutralize a dangerous excess of mineral acid. In pregnant animals we find the same principle evidenced in the capacity of the foetus to rob the mother of any such nutriment as its development requires.

The size of the visceral organs is regulated, in part, in accordance with the principle that they take from the blood-stream such nutrients as they require to carry on the work imposed upon them. Departures from the average development in the directions either of increase or decrease may, therefore, be considered as partially determined by the amount of work which has been required of the organs in question, especially if these organs remain normal in composition, and partially by the capability of the food to cause gain of the sort required.

The following bulletin contains in addition to economic data, the beginning of a series of studies of the effects of foodstuffs on animals. It consists of the results from three experiments, the conclusions from the first beginning on page 266, and from the second and third on page 295. A general summary of results is to be found on pages 301 to 305.

EXPERIMENT I

Objects. The objects of this experiment were (1) to compare wheat middlings, linseed oil meal, soy beans, tankage and germ oil meal as supplements to corn in the dry-lot fattening of hogs for market; (2) to compare full-feeding on these rations with the feeding of restricted amounts; and (3) to observe the effects of these rations on the composition of the flesh.

Method of experimentation. This experiment was conducted during the months of April and May, 1905. There were in all sixty-five hogs used in this experiment. They were divided into thirteen lots of five each. One of these lots was killed at the beginning of the experiment and the carcasses were subjected to all the tests which were later applied to the hogs in the experiment proper, this lot constituting the check or basis of comparison for the lots which were fed.

These hogs were all grade Poland Chinas and were about seven months of age at the time the experiment began. They weighed about 120 pounds each and were in good, thrifty growing condition. All had run upon bluegrass pasture during the preceding winter, and had received nothing but corn and water in addition to the feed which they picked up. They were a uniform lot and were fairly good in quality. The same proportion of gilts and barrows was kept in each experimental lot. These hogs were fed in small pens with cement floors, the sheds sheltering them being open on the south. On account of the fact that these hogs had all received the same treatment before they went into this experiment, they were given only one week's preliminary feeding in the experimental sheds.

The first weights were taken on April 1, before the evening feed, and all subsequent weights were taken, as in this case, before giving the evening ration. With their first experimental feed they were given medicine for the purpose of expelling any such intestinal parasites as they might have with them. This procedure has been adopted as a standard method of operation in our feeding experiments, because we find that round-worms are so exceedingly common in swine that a feeding experiment undertaken with animals which have not been freed from these parasites is not at all certain to give accurate results. The dose administered in this case was three grains of santonin and five grains of calomel for each 80 pounds of live weight. This has proven to be an especially effective remedy.

The hogs were fed twice daily, at regular times. All feed was ground into a moderately fine meal, and fed wet with water, until just thin enough to pour handily. Nothing in the way of ashes or charcoal was given to any lot, but salt was regularly administered with the grain, to the amount of one ounce per head per day. The hogs were watered regularly after feeding, and after the weather became warm, a third time at noon. The experiment progressed from start to finish without any accident or sickness to detract from the reliability of the results. The weather throughout the whole of the experiment was ideal for our purpose.

TABLE I: RATIONS USED

Lots	Rations	Amounts fed
1	Corn meal	Ad libitum.
2	Corn meal, 18.25 percent; wheat middlings, 81.75 percent	" "
3	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	" "
4	Corn meal, 80.43 percent; soy beans, 19.57 percent	" "
5	Corn meal, 91.94 percent; tankage, 8.06 percent	" "
6	Corn meal, 60.64 percent; germ oil meal, 39.36 percent	" "
7	Corn meal	" "
8	Corn meal, 18.25 percent; wheat middlings,, 81.75 percent	1.084 lbs. for each pound eaten by Lot 7.
9	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	1.0214 lbs. for each pound eaten by Lot 7.
10	Corn meal, 80.43 percent; soy beans, 19.57 percent	1.016 lbs. for each pound eaten by Lot 7.
11	Corn meal, 91.94 percent; tankage, 8.06 percent	1.016 lbs. for each pound eaten by Lot 7.
12	Corn meal, 60.64 percent; germ oil meal, 39.36 percent	1.01 lbs. for each pound eaten by Lot 7.
13	Check lot; killed at beginning of experiment.	

The nutritive ratio was the same, 1:6.5, in each case except where corn was fed alone as to Lots 1 and 7.

As will be seen by inspection of the above table, there were twelve lots of hogs fed in this experiment. The thirteenth lot, to which we shall refer throughout the bulletin as the "check lot," was killed just as the other twelve went on feed, this one furnishing us a basis for judgment as to the changes produced during the fattening process. Lots 1 to 6 were fed on the same rations as Lots 7 to 12, the only difference being that the first set were fed to the limit of their appetites, while in the second set each lot was given just such amount of feed as was necessary to provide the same number of pounds of digestible nutriment as was consumed by Lot 7, which received corn alone, *ad libitum*. All of these rations, except those consisting of corn meal alone, were so compounded that the nutritive ratio, or proportion of proteid to non-proteid organic nutriment, was as 1:6.5; hence it is seen that Lots 1 to 6 furnish us evidence as to the comparative usefulness of these rations as ordinarily fed, while Lots 7 to 12 show us the comparative value of the same amounts of digestible organic nutriment in the same nutritive ratio, but from different sources.

Corn meal was fed in both series as a standard ration. Corn meal and wheat middlings were used in rations Nos. 2 and 8, because of the high esteem in which middlings is held by pork producers the country over. In order to get a ration having a nutritive ratio of 1:6.5, it was necessary to feed the middlings in larger proportion to corn than that in which we ordinarily use this feed for profit.

Rations 3 and 9 are composed of corn and linseed oil meal, a combination which we have found especially efficient and economical. Rations 4 and 10 are composed of corn meal and soy beans. Soy beans were used because they constitute the only concentrated, nitrogenous, grain supplement to corn which we commonly find it profitable to produce on the farms of this region.

Rations 5 and 11 are composed of corn meal and digester tankage. This supplement has an advantage over many others in that its greater concentration renders it unnecessary that it be handled in such large quantities as the grain supplements. Tankage is dried and ground meat scrap, with most of the fat removed.

Rations 6 and 12 are composed of corn meal and germ oil meal. This supplement is a by-product from the manufacture of glucose from corn. We used this feed in order to balance the corn ration with a corn product. This combination gives us an interesting ration to compare with those in which the corn is balanced by foodstuffs produced by other plants.

TABLE II: CHEMICAL COMPOSITION OF FEEDS USED IN EXPERIMENT I

Feeds	Water	Protein Nx6.25	Nitrogen-free extract	Crude fiber	Ether extract	Ash	Phosphorus	Lecithin
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Corn meal............	15.87	8.06	69.06	1.92	3.64	1.45	.235	.111
Wheat middlings......	12.77	14.19	59.26	5.60	4.53	3.65	.901	.739
Linseed oil meal. ...	9.32	31.31	41.85	8.02	4.50	5.00	.81	.922
Germ oil meal........	10.50	19.69	49.27	8.52	9.17	2.85	.74	1.042
Soy beans............	10.87	30.13	31.90	4.15	17.65	5.30	.745	1.827
Tankage..............	7.90	54.00	......	....	10.44	22.25	3.238	1.126

This table sets forth the chemical composition of the food stuffs used. It will be noted that the corn meal contained rather more moisture than this foodstuff usually carries in the spring. It was also rather low in protein and in fat. The wheat middlings was low in protein and high in fiber, ash and phosphorus. Its appearance and composition strongly suggested ground bran. The linseed oil meal was bought for the "old process" article, but the oil content was low. The germ oil meal was in every way typical of this by-product as usually found on the market. Its high oil content makes it necessary that it be fed with care, especially since it also necessitates its being fed in large proportion with corn, if used as a supplement to this feed. The soy beans were particularly rich in fat, and were also about as rich in protein as was linseed oil meal. The tankage contained 54 percent of protein. The carbohydrate material present was not determined. It will be observed that the ash content of the vegetable foodstuffs used ranged from 1.45 percent in corn meal to 5.3 percent in soy beans, but that the tankage contained 22.25 percent. Its high ash content was due largely to the fact that it contained a considerable amount of bone.

The lecithin content of these feeds was considered because of the interesting relation of lecithin to certain tissues in the body.

Lecithin is a wax-like substance composed of fat, glycero-phosphoric acid and a nitrogenous group called choline. It is found in all plant and animal cells, and its abundance in gland cells and in the germs of seeds, which contain great numbers of cell nuclei, suggests that it is a nuclear constituent. It is also abundant in the sexual elements, in eggs and in the nervous system. Its relation to living processes is apparently important, but its significance is as yet not understood.

Lecithin is a highly valuable nutrient, because of the wide range of its usefulness. Its importance as a constituent of the food depends on whether or not the animal can build up lecithin from other phosphorus compounds. This question is not yet finally settled.

TABLE III: DIGESTIBILITY OF FEEDS USED

Feeds	Number of trials	Dry matter	Protein (Nx6.25)	Crude fiber	Nitrogen-free extract	Ether extract	Authority
		Percent	Percent	Percent	Percent	Percent	
Corn..................	4	92.0	86.0	40.0	95.0	76.0	Wolff
Wheat middlings.....	2	76.5	76 2	48.2	86.2	94.5	Minn. Sta.
Linseed oil meal.......	2	77.5	86.0	12.0	85.0	80.0	Minn. Sta.
Germ oil meal*........	4	92.0	86.0	40.0	95.0	76.0	Wolff
Soy beans**...........	1	81.9	91.1	71.2	76.3	85.7	Mass. Sta.
Tankage***..........			97.0			87.0	Wolff

* Assumed same as corn.
** Digestibility with sheep.
*** These coefficients determined for meat meal.

Our knowledge of the digestibility of even the commonest foodstuffs for swine is exceedingly scanty. We have assumed that the digestibility of the different nutrients in germ oil meal was the same as in the corn from which this foodstuff was made. The only digestion experiments with soy beans, known to us, were conducted with sheep at the Massachusetts Station, and these figures were used in this experiment. Since we had no digestion tests with tankage, we were obliged to assume that the protein and the ether extract in this feed have the same digestibility as in meat meal, upon which Wolff conducted a digestion experiment many years ago. Recent work by Dietrich of the Illinois Station indicates that the figure used for digestibility of protein in tankage is too high. The digestion coefficients which we have used for corn, were also determined by Wolff. The digestion coefficients of linseed oil meal and wheat middlings were made at the Minnesota Experiment Station.

Some of the assumptions above noted are unwarranted, and doubtless introduce errors into our work, but are believed not to be grossly misleading. Accuracy would have required that digestion experiments be conducted in connection with the test, but this was not possible.

TABLE IV: NUTRIENTS IN ONE HUNDRED POUNDS OF RATIONS AS COMPOUNDED

Lots	Feeds	Digestible protein	Digestible carbohydrates	Digestible ether extract	Phosphorus	Lecithin
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	Corn meal.........	6.93	66.37	2.77	.24	.11
2	Corn meal;...... ..	1.26	12.11	.51	.04	.02
	wheat middlings...	8.84	43.97	3.50	.74	.60
	Total.....	**10.10**	**56.08**	**4.01**	**.78**	**.62**
3	Corn meal;	5.70	54.56	2.28	.19	.09
	linseed oil meal. ..	4.79	6.50	.64	.15	.16
	Total......	**10.49**	**61.06**	**2.92**	**.34**	**.25**
4	Corn meal;.......	5.57	53.38	2.23	.19	.09
	soy beans..........	5.37	5.34	2.96	.15	.36
	Total.....	**10.94**	**58 72**	**5.19**	**.34**	**.45**
5	Corn meal;........	6.37	61.02	2.55	.22	.10
	tankage...........	4.22		.73	.26	.09
	Total......	**10.59**	**61.02**	**3.28**	**.48**	**.19**
6	Corn meal;........	4.20	40.25	1.68	.14	.07
	germ oil meal.....	6.66	19.76	2.74	.29	.41
	Total......	**10.86**	**60.01**	**4.42**	**.43**	**.48**

It must be borne in mind that the specific effects of each of these rations is dependent on the proportions in which the constituent foodstuffs are present. The characteristic effects of the rations containing wheat middlings and linseed oil meal, for instance, depend on the presence of these supplements in a particular proportion. Linseed oil meal contains considerably more lecithin than does wheat middlings, but the ration containing the oil meal contains very much less lecithin than the one containing the middlings; this because the oil meal was fed in so much smaller proportion to the corn than the middlings. Hence it is well to bear in mind that we are observing the characteristics, not of individual foodstuffs, nor of chemical compounds, but of *rations*. This gives an especial significance to Table IV, page 246.

The corn ration, compared with the others, is low in protein, in phosphorus and in lecithin, but high in carbohydrates.

The wheat middlings ration is the least concentrated of all, since it contains the highest percentage of indigestible fiber. It contains more phosphorus and lecithin than any other ration.

The remaining four rations are about equally concentrated, though the linseed oil meal and soy bean rations contain less phosphorus than the tankage and the germ oil meal rations. The soy bean ration also contains less starch and more fat than the tankage and the linseed oil meal rations.

The palatability of these rations is indicated by the amounts eaten by Lots 1-6. (Table V, page 248.) Many have considered corn to be more palatable to hogs than other foodstuffs, but these hogs ate less of the ration of corn alone than of any other except the ration of corn and germ oil meal. This last was a hard ration to feed. In general it was more palatable than corn, but after eating of it heartily for several days, the pigs would suddenly go off feed badly. It was hard to get their measure. The germ oil meal is bulky when wet, swelling through the absorption of a large amount of water. While it may be useful as a component of a more varied ration it was not satisfactory as a single supplement to corn.

It seems likely that the unsatisfactory character of this ration was due to the fact that all of its proteids came from corn.

Animals construct the proteids of their bodies from proteids only. The food proteids, however, cannot be built up into animal tissues until they have been split up into the primary nitrogenous groups from which they are composed, and then rearranged and reunited to form the particular compounds required by the animal.

TABLE V: TOTAL NUTRIENTS FED

Lots	Rations	Total feed consumed	Digestible protein	Digestible carbo-hydrates	Digestible ether extract	Phos-phorus	Lecithin
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	Corn meal...	1292.5	89.57	875.83	35 80	3.04	1.44
2	Corn meal;........ wheat middlings..	1456.5	147 13	816.77	58.33	11.35	9.09
3	Corn meal; .... linseed oil meal	1799.0	188.68	1098.50	52 50	6.09	4.62
4	Corn meal; .... . soy beans.....	1729 0	189.27	1015.27	89.73	5.78	7.73
5	Corn meal;....... . tankage	1786.0	189.20	1089.83	58.55	8.51	3.44
6	Corn meal; .... germ oil meal . ..	1277.5	138.81	766.63	56.51	5.54	6 09
7	Corn meal	1306.5	90.54	867.12	36.19	3.07	1.45
8	Corn meal; ... . wheat middlings. ..	1297.6	131.08	727.66	51.96	10.13	8.09
9	Corn meal; . .... linseed oil meal......	1333.7	139.88	814.38	38.91	4.52	3.42
10	Corn meal; .... soy beans.......	1327.5	145.32	779.51	68.89	4.44	5.93
11	Corn meal; .... tankage.............	1327.5	140.62	810.05	43.52	6.33	2.56
12	Corn meal; .... germ oil meal.......	1258.5	136.75	755.22	56.66	5.46	6.00

It is easily conceivable that the proteids of corn should not contain these primary nitrogenous groups of the kinds and in the proportions most useful for the building up of the proteids of the hog's body.

The rations of mixed origin furnish a greater variety of plant proteins, from which the animal can select constituents more exactly suited to its particular needs.

The wheat middlings ration was eaten in larger quantity than the two above mentioned, but the hogs consuming this feed did not eat heartily and were easily forced off feed.

Recent experiments indicate that the unfavorable effects of wheat bran and middlings, when used in too large proportion to other feeds, are due to the excessive amounts of magnesium which they contain.

Mineral salts exercise a regulative function over a great number of the vital processes in animals. The maintenance of this control requires that the various salts be present in the liquids of the body in definite quantitative relation, one to another. (See Bul. 201, Ohio Agr. Exp. Sta.).

Magnesium and calcium salts appear to be antagonistic in their action, and the introduction of excessive quantities of magnesium salts into the circulation seems to result in the withdrawal of calcium from certain tissues, to protect others from the action of magnesium. The excess of both is then excreted.*

Thus the consumption of feeds like bran and middlings, which are characterized by very high magnesium contents, may cause a considerable loss of calcium from the body.

The failure of certain investigators to maintain hogs on wheat middlings alone, may be due to this factor, as may also be the existence of "bran disease", "shorts disease", or "miller's horse rickets" in horses.

The author has made considerable use of wheat bran as a food for brood sows, and has regarded it very highly. The above facts regarding the effects of an excess of magnesium in the body recall to mind, however, a number of sows which broke down while on this ration. Some recovered when the pigs were taken away. Others had to be killed. The indications are that an excess of magnesium and the consequent loss of calcium from the body, together with the removal of salts through lactation, were responsible for these troubles. The use of chalk in the ration, with the bran, would certainly have tended to alleviate the unfavorable symptoms.

At the close of the experiment the hogs receiving linseed oil meal were cleaning up their feed much better than any others. They were consuming feed in excess of their ability to digest it, as was shown by the appearance of undigested meal in the feces, but their appetites never faltered.

The linseed, soy bean and tankage rations were each eaten practically to the full limit of the capacity of the hogs, so that the differences in palatability are not fully shown by the figures. The oil meal ration was consumed much more rapidly after the sixty days full-feeding than either the tankage or the soy bean rations.

The wheat middlings ration contained much the most phosphorus and lecithin. Corn is low in both, but corn and soy beans together, make a ration which is rich in these constituents.

*Mendel and Benedict: Journ. Biol. Chem., Vol. 4, No. 2; Amer. Journ. Physiol., Vol. 25, No. 1.
Malcom: Journ. Physiol., Vol. 32, p. 182.
Meltzer and Auer: Amer. Journ. Physiol., Vol. 14, p. 366; Vol. 21, p. 400.
Forbes: Bul. 207, Ohio Agr. Exp. Sta., pp. 34, 37, 39, 44, 47.

The tankage ration, with its high content of bone, was rich in phosphorus, but its lecithin content was low.

Lots 7-12, the limited ration series, were each to have been fed the same amount of digestible nutriment, but our plans did not work out with absolute exactness. The wheat middlings and germ oil meal lots were so capricious in their appetites that they had to be allowed the liberty of going their own gait, and they fell behind the standard.

The four other lots each received exactly the same number of pounds of digestible nutriment, but when the non-nitrogenous constituents were computed to "starch-equivalent", as in this table, the total amounts of nutriment no longer appear to be the same, because of the differences in the fat-content of the rations, fat having a higher value than starch.

As the final results stand, however, we have a basis for a very satisfactory comparison between the three most profitable rations fed, those containing linseed oil meal, soy beans, and tankage, on two levels as to quantity.

TABLE VI: GAIN IN WEIGHT PER POUND DIGESTIBLE PROTEIN AND NON-NITROGENOUS STARCH-EQUIVALENT

Rations	Lot	Total nutriment consumed	Gain per pound nutriment	Lot	Total nutriment consumed	Gain per pound nutriment
		Lbs.	Lbs.		Lbs.	Lbs.
Corn............	1	1033.3	.265	7	1044.5	.275
Corn; wheat middlings ..	2	1103.9	.344	8	983.4	.374
Corn; linseed oil meal.....	3	1413.2	.356	9	1047.6	.364
Corn; soy beans...... ..	4	1419.9	.358	10	1090.2	.328
Corn; tankage......	5	1419.6	.354	11	1055.2	.327
Corn; germ oil meal. ...	6	1041.05	.306	12	1025 6	314

In the full-fed series, Lots 1-6, the gain per pound of digestible nutriment was less with the corn lot than with any other; the corn and germ oil meal ration was also distinctly less efficient than the other mixed rations. The linseed oil meal, tankage, and soy bean rations were found to have almost exactly the same ability to cause gain in weight, while the wheat middlings ration was less efficient in this regard.

In the limited ration series, Lots 7-12, the rations of corn, and of corn and germ oil meal, proved again to be less efficient than the others. The higher relative efficiency of the wheat middlings, and linseed oil meal rations in this series, if these figures represent the actual facts, would lead us to the conclusion that they have a usefulness which is due to factors which are as yet obscure. It is possible that the high phosphorus content of the middlings ration was an advantage, and that its high fiber content helped to satisfy the pigs. During most of the experiment this lot was really fed *ad libitum*. The linseed oil meal, soy bean and tankage lots suffered from a constant affliction of appetite, which may have retarded their fattening.

Too close a comparison should not be drawn between the results in these two series, because the two rows of pens were not exactly alike, there being slightly more sunshine in the pens of the limited ration series. The corn straight, the wheat middlings, and the germ oil meal rations, which were really fed *ad libitum* in both series, were all slightly more efficient in the second one.

It is impossible to make a statement of the financial outcome of such a comparison of feeds, which will be at the same time useful and true. The reason is that market conditions are never the same at two different times, or in two different places. The relative prices of feeds today, in any given market, do not apply in any other market, and in all probability will never again recur.

We would suggest that the cost of pork made from these rations be calculated as follows, using such prices for feeds as prevail at the time and place of interest.

Suppose corn meal to cost 56 cents per bushel, linseed oil meal \$30.00 per ton, and tankage \$40.00 per ton; or corn 1 cent per pound, oil meal 1.5 cents per pound and tankage 2 cents per pound. (See Table VII, page 252.)

With Lot 1 it took 471.7 pounds of corn to make 100 pounds of pork. At 1 cent per pound this corn would cost \$4.72. With Lot 3, receiving corn meal and linseed oil meal, there were required to produce 100 pounds of pork, 357.6 pounds of feed, of which 17.79 percent or 63.62 pounds were oil meal, (cost $63.62 \times 1.5 = 95.4$ cents), and 82.21 percent,or 293.98 pounds were corn, (cost \$2.94). Adding these two costs, \$0.95 and \$2,94, we find that 100 pounds of pork cost \$3.89.

With Lot 5, receiving corn meal and tankage, there were required 355.8 pounds of feed to make 100 pounds of pork. Of this feed, 91.94 percent, or 327.12 pounds, were corn—cost \$3.27; while 8.06 percent, or 28.68 pounds, were tankage—cost \$0.57. Adding these costs of corn and tankage, \$3.27+.57=\$3.84, the cost of 100 pounds of pork with this ration.

In considering the replacement values of the supplements, as set forth in the fourth, fifth and sixth columns of figures in Table VII, it is necessary to bear in mind the fact that pork is not

TABLE VII: FEED CONSUMED, GAINS IN WEIGHT, AND VALUATION OF SUPPLEMENTS

Lots	Rations	Grain per cwt. gain	Average daily gain	Average daily feed	Values per ton of supplements corresponding to values of corn			Average initial weight	Average final weight
					Corn $ .40 bu.	Corn $ .50 bu.	Corn $ .60 bu.		
		Lbs.	Lbs.	Lbs.				Lbs.	Lbs.
	Series A. Ad libitum								
1	Corn meal	471.7	.91	4.31				114.2	169.0
2	Corn meal, 18.25 percent; wheat middlings, 81.75 percent	383.3	1.27	4 85	$19.92	$22.40	$26.87	117.4	193.4
3	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	357.6	1.68	6.00	37.98	47.47	56 90	119.8	220.2
4	Corn meal, 80.43 percent; soy beans, 19.57 percent	340.4	1.69	5.76	40.56	50.73	60.94	118.6	220.2
5	Corn meal, 91.94 percent; tankage, 8.06 percent	355.8	1.67	5.95	67.73	84.38	101.82	116.6	217.0
6	Corn meal, 60.64 percent; germ oil meal, 39.36 percent	401.1	1.06	4.26	19 90	24 84	29 90	120.1	183.8
	Series B. Limited quantity								
7	Corn meal	454.5	.96	4.35				119.5	177.0
8	Corn meal, 18.25 percent; wheat middlings, 81.75 percent	352.6	1.23	4.32	$19.76	$24.70	$29.63	121.0	194.6
9	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	350.1	1.27	4.44	40.20	50.42	60.38	120.0	196.2
10	Corn meal, 80.43 percent; soy beans, 19.57 percent	370.8	1.19	4.43	32.46	40.52	48.78	120.0	191.6
11	Corn meal, 91.94 percent; tankage, 8.06 percent	384.8	1.15	4.43	50.35	62.92	75.44	116.6	185.6
12	Corn meal, 60.64 percent; germ oil meal, 39.36 percent	390 5	1.07	4.16	21.02	26 28	31 48	120 6	185.0

necessarily made most cheaply by the use of the supplement having the highest replacement value, as was demonstrated by the author in Missouri Bulletin No. 65.

Consider, for instance, the above computation of the cost of pork. The cost is practically the same where linseed oil meal, and where tankage are used, even though tankage has a very much higher replacement value than linseed oil meal, as is shown in Table VII, on page 252. This is due to the higher cost of tankage, and the smaller percentage of tankage used to balance the ration.

Comparing corn alone with the supplemented rations, we find that the linseed, tankage, and soy bean rations made about 85 percent more gain in the same time. The longer the feed, the greater is the loss of possible profit by feeding corn by itself.

The wheat middlings rations were more efficient than corn alone, the gain being greater, and the feed required being less. It must be borne in mind, however, that the character of the increase was very different in these two cases. The middlings hogs grew, but did not fatten much. The corn-fed hogs were perceptibly smaller, but fatter. The middlings hogs had conspicuously heavy coats of hair.

The fourth, fifth and sixth columns of figures state the costs of the supplements at which it would be an even thing whether they be used with the corn or not. If the supplements can be purchased at prices less than those stated, they will return a profit; otherwise not.

As corn varies in price between 40 and 60 cents per bushel, wheat middlings may be valued between $19.92 and $26.87 per ton; that is, to make it an even thing whether the middlings be used with the corn, or the corn be fed alone.

In the same way linseed oil meal varies in value, in terms of corn saved by its use, between $37.98 and $50.90 per ton; soy beans between $40.56 and $60.94 per ton; tankage between $67.73 and $101.82 per ton, and germ oil meal between $19.90 and $29.90 per ton.

The linseed oil meal, soy bean and tankage rations returned very satisfactory profits, and each produced gains in weight of about 1.7 pounds per head, per day, at about the same expenditure of feed. These foodstuffs will still return a profit at considerably increased cost, as is indicated by the valuations in the fourth, fifth and sixth columns of figures.

The soy bean has the advantage of being capable of successful home production. This test shows it to be particularly valuable as a hog feed. The method of this experiment furnishes a very satisfactory comparison between this feed and the others used, but for profit we would doubtless use another system. For fall feeding the beans may be "hogged off", corn being fed in addition, and the hogs being restricted as to range over the field, by a movable fence. For winter feeding the beans may be cut a little early, cured as hay, and fed as a supplement to corn, without preparation.

The germ oil meal lots were a disappointment. This corn product seems not to be the proper thing to use as a supplement to corn; other feeds are better adapted to this purpose. The ration was neither cheap, nor efficient, nor palatable, and the gains made were not large.

The linseed oil meal, soy bean, and tankage hogs were much fatter than the corn and middlings lots. The linseed oil meal hogs graded "prime" in condition, and possessed that uniformly high finish which has made this feed a favorite with breeders of fine stock. The soy bean and tankage lots were graded "choice", being not quite so fat nor so uniformly fat as the linseed lot. The germ oil meal lot graded "good," was fatter than either the corn or the middlings hogs, and ranked ahead of the corn lot, but much behind the middlings lot in apparent growth of frame.

From the limited ration series, Lots 7-12, we may draw this practical conclusion: The less gain a hog is making, the more nearly does corn become a perfect food, and the less will be the profit from the use of nitrogenous supplements. Large consumption of feed and large gains in weight are essential to the most profitable use of supplementary feeds. Corn is more rich in protein than is necessary in a mere maintenance ration, but the further we get from the maintenance ration, that is, the more flesh we produce in a given time, the less efficient is corn alone, and the greater is the need of supplements. This principle receives constant recognition from dairymen, who know that the more milk a cow produces, the narrower must be her ration, but we do not happen to have seen the point mentioned in connection with meat production. It is, of course, so obviously true as to need no proof.

After the completion of the feeding test, the sixty hogs were shipped to a small packing-house at Alton, Illinois, where arrangements had been made for the killing.

After the hogs were dressed, the carcasses were cooled, and the tenderloin muscles dissected out, weighed and placed in screw-top bottles with rubber rings to prevent evaporation.

A cross-section taking in the sixth rib was procured from each hog. Each cross-section, as cut out, was wrapped in parchment paper, to prevent evaporation, until it could be sampled for analysis.

TABLE VIII: AVERAGE SLAUGHTER WEIGHTS

Lot	Rations	Live-weight Lbs.	Gross dressed weight Lbs	Leaf-lard Lbs.	Kidneys Ozs.	Heads and jowls Lbs.	Lungs Lbs.	Heart Ozs.	Liver Lbs.	Spleen Ozs.	Tender-loin muscles* Ozs.	Percent dressed to live weight**
1	Corn	173.8	132.8	4.61	6.15	13.03	1.78	8.38	2.78	3.10	5.43	76.4
2	Corn; wheat middlings	196.0	146.0	3.92	8.60	13.70	2.63	10.03	3.74	3.83	7.63	74.5
3	Corn; linseed oil meal	225.6	175.1	5.85	8.65	15.94	2.40	10.83	3.83	4.05	7.10	77.6
4	Corn; soy beans	223.8	174.0	6.34	8.68	16.29	2.19	10.13	3.89	3.78	6.68	77.7
5	Corn; tankage	223.6	173.0	6.47	8.13	16.00	1.96	10.20	3.64	3.35	6.53	77.4
6	Corn; germ oil meal	190.2	143.7	4.84	7.03	13 39	2.39	9.00	3.24	3.25	6 44	75.6
7	Corn	183.2	141.2	6.48	6.95	13.06	1.61	8.20	2.94	2.53	4.78	77.1
8	Corn; wheat middlings	198.2	146.2	4.00	8.70	13.88	2.24	10.03	3.71	3.70	6.85	73.8
9	Corn; linseed oil meal	203.6	156.4	5.12	7.53	13.81	1.80	10.30	3.56	3.58	6.78	76.8
10	Corn; soy beans	196.0	152.6	5.07	8.78	14.54	2.16	10.18	3.76	3.35	6.08	77.8
11	Corn; tankage	194.4	150.5	4.82	7.13	14.44	1.64	9.70	3.40	3.02	6.15	77.4
12	Corn; germ oil meal	192.4	143.5	4.17	7.75	14 09	1.80	8.95	3.40	3.23	6.75	74.6
13	Check lot	120.6	87.5	2.29	5.21	6.75	1.13	7.25	2 46	2.78	4.61	72.6

* Weight of one muscle. ** At Columbia.

In preparing them for sampling, the skin and bones were removed, and the remainder repeatedly run through a sausage mill so that the parts might be well mixed. Composite samples were prepared from each lot of five pigs, and after much grinding and mixing were put into small bottles, packed in an ice-cream packer, and expressed to Columbia for analysis. The tenderloins were similarly treated.

As the carcasses were being cut up, each was examined by the superintendent of the packing plant. None were found objectionably soft. The linseed oil meal hogs were characterized by conspicuous thickness, firmness, and especially evenness, of the covering of fat. The butchers learned in a very few minutes to pick out those that had received oil meal, by their marked excellence. They were especially interested because it had been their belief that this feed produced soft pork.

The soy bean hogs were slightly less firm than the linseed oil meal hogs, but not objectionably so. The tankage hogs also occasioned favorable comment.

In general, those hogs which were least fat were least firm in the fat. This explains the fact that the middlings hogs were the softest, they being the least fat. A middlings-fed hog that is finished has an unexcelled, brittle hardness of fat.

The germ oil meal hogs were also too backward in condition to appear to especial advantage. The most noticeable thing about the cutting, however, was the relative development of fat and lean in the carcasses. Every hog which was conspicuous for the thickness of its lean meat came from a wheat middlings lot. The characteristic of the corn-fed hogs was that these appeared to have deposited much fat within the lean, but were not especially thick in either fat or lean.

The linseed oil meal, and soy bean hogs had the appearance of having both grown and fattened, neither function predominating to a noticeable extent.

These hogs, weighing about 120 pounds at the beginning of the experiment, were fed out in sixty days, the best of them to good fat-hog weights, as is seen in the first column of figures in Table VIII, page 255.

The last column gives the percentage of dressed to live-weight. The lack of proper scales at the packing house made it necessary that we base this figure on our Columbia weights, hence the hogs appear to have dressed a low percentage of carcass.

In the full-fed series, Lots 1 to 6, the linseed, soy bean and tankage lots outdressed the corn lot in spite of having heavier waste parts. They were decidedly fatter.

In the limited ration series, Lots 7 to 12, the soy bean and tankage lots outdressed the corn lot, while in both series the wheat middlings lot ranked last as to percentage of dressed to live-weight. They had fattened very little and their offal parts were well developed.

These weights of parts are here set down to give them permanent record, but their true significance is not manifest in this form; the next three tables being so computed as to set forth their real usefulness.

In both series, (Table IX, page 258), the corn lots yielded the lowest percentage of net to gross dressed weight, while the middlings lots in each series yielded the highest percentage, followed in each case by the linseed oil meal lot. The net dressed weight is the gross dressed weight minus the head, leaf-lard and kidneys, and in some establishments, the ham facings. It represents the hog as sent to the cooler. If in the development of the hog, the head and the leaf-lard should fall behind the muscular system in rate of increase, we would have an increased percentage of net to gross dressed weight. This is just what took place in the middlings lots. Thickness of flesh, whether it be due either to development of fat or muscle, tends to increase the percentage of net to gross dressed weight. This is of importance to the packer, since the net dressed weight is worth more per pound than the gross dressed weight.

The percentage of leaf-lard is a good indication of the development of the internal fat generally. An abundance of internal fat in a hog is much in the packer's interest, but is not an advantage to a breeding animal on the farm. Pressure of internal fat upon reproductive and other vital organs cannot fail to operate disadvantageously, through impairment of the circulation of the blood in those parts.

The largest proportion of kidneys, lungs, heart, liver and spleen were in both series found in the wheat middlings lot. This is partially due to the fact that these hogs were not fat, but largely also to the fact that these parts were well developed, as will be apparent from an inspection of Table VIII, page 255. The lungs of the middlings lots, Nos. 2 and 8, were both relatively and absolutely larger than any others. The tenderloin muscles were also large, in Lot 2 being both relatively and absolutely larger than in any other lot, while in Lot 8 they were absolutely heavier than any other in the second series, but relatively not heavier than in the germ oil meal lot. The only difference known to exist between the middlings rations and those fed to the other lots, which might account for this remarkable showing, is in the phosphorus content, the middlings rations being especially rich in easily assimilable phosphorus compounds.

TABLE IX: RELATION OF DIFFERENT PARTS TO DRESSED CARCASS

Lot	Ration	Percent net to gross dressed weight	Percent leaf-lard	Percent kidneys	Percent head and jowl	Percent lungs	Percent heart	Percent liver	Percent spleen	Percent tenderloin
1	Corn.........	86.4	3.47	.290	9.81	1.34	.394	2.09	.146	.255
2	Corn; wheat middlings.................	87.6	2.69	.368	9.38	1.80	.430	2.56	.164	.327
3	Corn; linseed oil meal	87.2	3.34	.309	9.10	1.37	.387	2.19	.144	.254
4	Corn; soy beans...........	86.7	3.64	.312	9.36	1.26	.364	2.24	.136	.240
5	Corn; tankage..........	86.7	3.73	.294	9.24	1.13	.367	2.10	.121	.236
6	Corn; germ oil meal.....	87.0	3.43	.242	9.32	1.66	.391	2.25	.141	.280
7	Corn.................	85.9	4.59	.308	9.25	1.14	.363	2.08	.112	.211
8	Corn; wheat middlings.....	88.8	2.73	.372	9.49	1.53	.428	2.54	.158	.293
9	Corn; linseed oil meal.................	87.6	3.27	.301	8.83	1.15	.412	2.28	.143	.271
10	Corn; soy beans.....	86.8	3.32	.359	9.54	1.42	.417	2.46	.137	.249
11	Corn; tankage	86.9	3.13	.296	9.59	1.09	.403	2.26	.158	.255
12	Corn; germ oil meal...	87.0	2.90	.338	9.82	1.25	.390	2.37	.125	.294
13	Check lot...............	89.3	2.62	.475	7.71	1.29	.516	2.81	.140	.329

It is interesting to note that in Lot 13, the check lot, which was killed at the beginning of the experiment, the percentages of kidneys, heart, liver, spleen and tenderloin muscle were all larger than in any of the other lots after sixty days' feeding. The lungs, however, in a number of cases were relatively heavier in the fattened hogs than in this check lot.

TABLE X: PERCENT OF INCREASE IN LIVE WEIGHT AND IN CERTAIN PARTS AND ORGANS

Lots	Rations	Live-weight	Leaf-lard	Kid-neys	Lungs	Heart	Liver	Spleen	Tender-loins
1	Corn................	52.2	112.4	24.74	66.4	22.16	19.31	17.87	24.31
2	Corn;wheat middl'gs.	67.0	75.8	69.62	139.1	42.07	56.49	41.32	70.31
3	Corn; linseed oil meal	88.3	156 6	66.99	114 3	50.42	56.97	46.73	55.02
4	Corn; soy beans.....	88.7	181.8	69 53	97.3	42.08	60.74	38.46	47.46
5	Corn; tankage......	91.8	191.4	61.31	79.8	45.51	52.94	24.53	46.74
6	Corn; germ oil meal	58.4	112 3	35.45	111.5	24.65	32.24	17.32	40 30
7	Corn...............	53.3	185.5	34.69	43.8	14.21	20.49	—8.00	4.82
8	Corn; wheat midd'gs	63.8	74.0	66.35	98.2	37.96	50.20	32.61	48.26
9	Corn;linseed oil meal	69.7	124.0	45.37	60.7	42.86	45.30	29.24	48.03
10	Corn; soy beans....	63.3	122 4	69.50	92.9	41.19	53.46	20.93	32.75
11	Corn; tankage.......	66 7	117.1	41.47	50.5	38.37	42.85	8.63	38.20
12	Corn; germ oil meal.	59.5	82 1	48.75	59.3	23.45	38.21	16.19	46.42

In the sixty days of this experiment these 120-pound hogs increased in weight to the extent of 52-92 percent, according to the amount and kind of feed. Corn alone produced the smallest percentage of increase. The rations containing linseed oil meal, soy beans and tankage, in the full-fed series, produced practically the same percentage of increase in weight. They received the same amount of nutriment, (Table VI, page 250), and hence gained with equal efficiency. This gives us an excellent opportunity to judge of the difference in the kind of gain produced by these rations. The gain in leaf-lard differed considerably, the tankage ration being first, the soy bean ration being second, and the linseed oil meal ration third. The gain in tenderloin muscles also differed, but here the order of these three lots was just reversed, the linseed ration seeming to produce the most growth, the soy bean ration next, and the tankage ration last. The tankage ration contained the most corn. These three lots gained in lungs and in spleen in the same relative order as in the tenderloin muscles; that is, linseed oil meal first, soy beans second, and tankage third.

The wheat middlings ration, No. 2, with much less gain in live weight, gained very much more than the linseed oil meal, soy bean or tankage rations, in weight of tenderloin muscle. This ration excels all others in this regard in both series. In the full-fed series the middlings lot excelled all others in the gain made in kidneys and lungs, as well as in the tenderloin muscles.

The germ oil meal lot, No. 6, would appear from the increase in the leaf-lard, not to have fattened much better than the corn lot, but the additional protein caused a markedly greater increase in kidneys, lungs, liver and tenderloin muscles in this germ oil meal lot than in the corn lot, No. 1.

The corn lot seems to have made the least increase of all in live weight, kidneys, lungs, heart, liver, and tenderloin muscles. These observations are true in both series.

In the second, or limited ration series, Nos. 7-12, the corn, and the germ oil meal rations produced the least gain in weight. In this series the best comparisons may be made between Lots 7, 9, 10 and 11, since they received very nearly the same amounts of nutriment, as is seen in Table VI, page 250.

The corn lot, No. 7 in this series, gained much more in leaf-lard than other lots. It was last of all, however, in increase of every other part observed.

The kidneys and livers of the soy bean lot excelled others in gain in weight, while in the middlings lot the lungs and tenderloin muscles were heavier than in other lots.

The data in this table have reference to the gain in each organ by itself, independent of all else. In the following table, No. XI, page 261, the gain in these organs is in each case referred to the gain in live weight, so that we are able to say that for each percent of gain in live-weight of the animal, each of these organs increased a certain part of one percent of its own weight. In case the animal were developing just symmetrically in all parts, the percent of gain in each one of these portions would be the same as in live-weight. The departures from this order are interesting and significant.

This table, more than any other, exhibits the real specific influence of these rations. In both series the corn lot gained in leaf-lard much more rapidly than in live-weight, and also gained relatively more in leaf-lard than any other lot. In all other parts except the lungs, the gain, relative to gain in weight of these corn fed hogs, is very low. It is probably more than a coincidence that the lungs and leaf-lard should exceed other parts in proportionate gain. These observations refer us to the two methods of disposal of the excess non-nitrogenous starch-equivalent which was present in the ration of these corn-fed hogs. They must lay it onto the body as fat, or work it off through the lungs as carbon-dioxide. These hogs in close confinement seem to have disposed of it largely by making it into fat; in fact, nearly all of these hogs, ten out of the twelve lots, gained in leaf-lard more rapidly than in live-weight or in any other part observed. In the two middlings lots, and in these alone, the relative gain in lungs was greater than in leaf-lard. In no one of the twelve lots is the gain in any other part observed as great in relation to gain in live-weight as in leaf-lard and lungs.

TABLE XI: INCREASE IN WEIGHT OF VARIOUS PARTS AND ORGANS IN RELATION TO GAIN IN LIVE WEIGHT

Lots	Rations	Leaf-lard	Kid-neys	Lungs	Heart	Liver	Spleen	Tenderloin
1	Corn..........................	2.15	.47	1.27	.425	.370	.342	.47
2	Corn; wheat middlings........	1.13	1.04	2.08	.628	.843	.617	1.05
3	Corn; linseed oil meal........	1.77	.76	1.29	.571	.645	.529	.62
4	Corn; soy beans.........	2.05	.78	1.10	.474	.685	.434	.54
5	Corn; tankage................	2.08	.69	.87	.495	.577	.267	.51
6	Corn; germ oil meal...........	1.92	.61	1.91	.422	.552	.296	.69
7	Corn;.........................	3.48	.65	.82	.267	.384	−.150	.09
8	Corn; wheat middlings.... ...	1.16	1.04	1.54	.600	.787	.511	.76
9	Corn; linseed oil meal..........	1.78	.65	.87	.615	.650	.420	.69
10	Corn; soy beans................	1.93	1.10	1.47	.651	.845	.331	.52
11	Corn; tankage	1.75	.62	.76	.575	.642	.129	.57
12	Corn; germ oil meal.........	1.38	.82	1.00	.394	.642	.272	.78

In each one of the twelve lots it is true that the relative gain of the spleen is less than that of any other part observed. Its function in the body seems to be fulfilled without so much increase in weight as occurs in these other organs.

The wheat middlings lots developed kidneys, lungs and tenderloin muscles to a greater extent than other parts.

In both series the corn, tankage and germ oil meal rations produced much smaller relative gains in weight of spleen than did other rations. These three rations are the ones made up most largely of corn.

TABLE XII: RELATION OF GROWTH TO INCREASED WEIGHT OF LEAF-LARD

Lot	Rations	Leaf-lard	Lungs	Spleen	Kid-neys	Heart	Liver	Tender-loin	Phos-phorus Lbs.
2	Corn; middlings...........	1.13	2.08	.617	1.04	.628	.843	1.05	11.35
3	Corn; linseed oil meal......	1.77	1.29	.529	.76	.571	.645	.62	6.09
4	Corn; soy beans	2.05	1.10	.434	.78	.474	.685	.54	5.78
5	Corn; tankage.............	2.08	.87	.267	.69	.495	.577	.51	8.51
1	Corn.......	2.15	1.27	.342	.47	.425	.370	.47	3.04

Arranging as above, Lots 1 and 5, from Table XI, page 261 we place them almost in order of relative gain in weight of tenderloin muscles, liver, heart, kidneys, spleen, lungs and the amount of phosphorus in the rations, and inversely as the relative gain in leaf-lard. In so doing we display the relative tendencies of these rations to cause growth and fattening. The observations made on the germ oil meal lot do not conform so closely to this order.

We beg to repeat, however, that these characteristics are not of the supplementary foodstuffs, but of the rations. It is of importance that this distinction be noted. The relative efficiency would certainly have been very different if these rations had been made up of the same foodstuffs in other proportions. It is a fair comparison, however, in the sense that these rations were as nearly as we could get them of the same proportionate content of digestible protein and non-nitrogenous starch-equivalent.

The tankage ration does not cause growth to an extent proportional to its phosphorus content, because its phosphorus is so largely in the shape of bone, the inorganic phosphorus of which appears to be limited as to usefulness.

In the second series the same tendencies are manifest, but the agreement is less orderly. These results are at best hardly more than suggestive since the method of work was necessarily crude under the conditions existing.

TABLE XIII: RELATION OF PHOSPHORUS TO DEVELOPMENT OF MUSCLE

Lot	Rations	Total phosphorus consumed	Total gain in weight of lot	Gain in weight of muscle of lot	Total lecithin consumed	Fat in muscle
		Grams	Lbs.	Percent	Grams	Percent
2	Corn; wheat middlings............	5149.3	380	70.2	4123.2	5.04
5	Corn; tankage................	3862.4	502	46.6	1560.4	5.17
3	Corn; linseed oil meal..............	2762.9	503	56.1	2095.6	4.01
4	Corn; soy beans.....................	2624.1	508	47.3	3506.3	4.79
6	Corn; germ oil meal..............	2512.5	318.5	40.3	2762.4	4.67
1	Corn...............................	1377.6	274	24.4	653.2	7.28
8	Corn; wheat middlings...........	4587.3	368	48.3	3669 6	4.54
11	Corn; tankage...........	2870.8	345	38.2	1161.2	3.92
12	Corn; germ oil meal..........	2475.3	322	46.4	2721.6	4.31
9	Corn; linseed oil meal.........	2048.5	381	47.9	1551.3	5.57
10	Corn; soy beans............	2015.8	358	32.6	2689.8	3.21
7	Corn	1392.6	287 5	4.7	657.7	8.29

This table shows both series arranged according to the phosphorus content of the total feed administered. There is no apparent connection between the phosphorus content of these rations and the gain in live-weight; nor between the phosphorus content and the percent of fat in the muscle; neither does the lecithin content of the ration seem to be closely in accord with these other items noted, but the phosphorus content in each series does correspond somewhat definitely with the gain in the weight of the tenderloin muscles, especially when we consider the fact that as previously observed, tankage carries its phosphorus mostly as bone. It is not impossible that the significant connection between the gain in muscles and the composition of the ration, should be between these organs and some other constituent or characteristic of the ration, which varies directly as the phosphorus. The probability, of course, is that this is an essential connection; that the phosphorus is used as a nutrient, and that at least those rations containing less phosphorus than the middlings rations do not contain as much of this element as is necessary to maximum muscular growth.

TABLE XIV: ANALYSIS OF TENDERLOIN MUSCLES

Lot	Rations	Water	Protein	Fat	Ash	Water in fat-free meat	Fat in water-free meat	Ash in fat- and water-free meat
		Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn..................	71.55	19.187	7.28	1.1076	77.38	25.77	5.282
2	Corn; wheat middlings	72.94	20.675	5.04	1.1505	76.81	18.62	5.225
3	Corn; linseed oil meal..	74.08	20.506	4.01	1.1790	77.17	15.47	5.381
4	Corn; soy beans.......	72.91	20.944	4.79	1.1228	76.58	17.68	5.035
5	Corn; tankage.........	73.66	19.783	5.17	1.1280	77.68	19.63	5.328
6	Corn; germ oil meal...	73.53	20.549	4.67	1.0760	77.13	17.64	4.936
7	Corn..................	71.52	19.033	8.29	1.0630	77.98	29 05	5.265
8	Corn; wheat middlings	73.58	20.581	4.54	1.1040	77.08	17.18	5.046
9	Corn; linseed oil meal..	72.56	20.456	5.57	1.1750	76.84	20.29	5.373
10	Corn; soy beans.......	74.14	21.224	3.21	1.1320	76.60	12.41	4.998
11	Corn; tankage........	73.93	20.593	3.92	1.1070	76.95	15.03	4.998
12	Corn; germ oil meal....	74.17	20.196	4.31	1.0540	77.51	16.69	4.898
13	Check lot............	73.53	19.926	4.61	1.1041	77.81	17.42	5.051

In both series the muscles of the germ oil meal lots have less ash, and the muscles of the linseed oil meal lots have more ash than is found in any other lots. These observations are true when the percentage of ash is computed, either on the basis of the meat as a whole, or on the fat- and water-free meat.

It is also worthy of note that in both series the corn lot ranks ahead of the middlings, soy bean, and germ oil meal lots as regards the percentage of ash in the fat- and water-free meat, though on the basis of the meat as a whole, the ash is low in the corn lots, because of the high percent of fat.

The percent of fat in the water-free meat shows the corn lot to have had much the fattest muscles; that is, more fat was deposited within the muscles than in other lots. This is of importance as indicating the quality of the flesh from a culinary standpoint, an intimate intermingling of fat and lean being considered essential to the highest quality.

The lower percentages of fat and the higher percentages of water were usually found associated. This would be expected on arithmetical grounds. When we compute the percentage of water in the fat-free meat, however, factors other than arithmetical ones seem to be operative. The percentage of water in the fat-free meat of the corn lots was high in both series.

The tendencies of corn to deposit fat within the muscles, and to restrict the development of the nitrogenous tissues, as is proven by the small muscles of the corn-fed hogs, are probably due to the fact that corn furnishes to the muscles more carbohydrate food than they have occasion to oxidize in the production of energy, it being, therefore, of necessity, deposited as fat; and further, to the fact that corn is probably lacking in the amount both of protein and phosphorus requisite to maximum muscular growth of a normal composition.

During this experiment these hogs, except in the corn lots, were receiving much narrower and more nearly normal rations than the one on which they had been raised. They were really corn-fed when the experiment began. It is interesting to note in comparing the check lot with some others that were fed for sixty days, that the change in feed, together with the increase in age, reduced the percentage of water in the fat-free meat even where it also reduced the precentage of fat in the meat.

The linseed oil meal ration, in the full-fed series, produced muscles that contained more water and ash, and less fat, than was found in any other lot. The fact of this low fat- and high water-content is difficult to explain. It seems not to have been due to fault in this sample, because the water in the fat-free meat of the cross-sections in the same series was also high; but in the limited ration series the oil meal lots, both with the muscles and the cross-sections, were characterized by a high fat content, and low percentage of moisture in the fat-free meat. The high proportion of ash to protein, however, holds in both samples of meat and both series, and so may be considered as characteristic of this ration.

TABLE XV: ANALYSIS OF THE MEAT OF THE CROSS-SECTIONS OF THE CARCASS.

Lots	Rations	Water	Protein	Fat	Ash	Water in fat-free meat	Fat in water-free meat	Ash in fat- and water-free meat
		Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	32.13	7.944	59.53	.422	79.39	87.71	5.060
2	Corn; wheat middlings	36.44	8.940	53.33	.460	78.08	83.90	4.497
3	Corn; linseed oil meal .	28.48	7.459	63.72	.391	78.50	89.09	5.013
4	Corn; soy beans.......	28.19	7.754	63.36	.407	76.94	88.23	4.817
5	Corn; tankage.........	29.55	7.635	62.75	.341	77.25	89.07	4.429
6	Corn; germ oil meal...	33.81	9.050	56.99	.395	78.61	86.10	4.350
7	Corn	28.51	7.010	63.94	.375	79.06	89.44	4.967
8	Corn; wheat middlings	32.95	8.623	57.77	.463	78.02	86.16	4.989
9	Corn; linseed oil meal..	29.77	7.947	61.97	.418	76.27	88.24	5.061
10	Corn; soy beans.......	36.90	9.644	52.66	.496	77.94	83.45	4.751
11	Corn; tankage.........	33.40	8.862	56.92	.454	77.53	85.47	4.690
12	Corn; germ oil meal..	34.76	9.307	55.05	.538	77.33	84.38	5.280
13	Check lot.............	43 55	11.929	42.80	.726	77.13	75.82	5.322

In the sampling of the meat of the cross-sections, difficulties were encountered which were not satisfactorily overcome, and on this account these figures do not represent the facts with reference to the carcasses, with quite the definiteness that was desired.

The percent of fat in these cross-sections is due very largely to the subcutaneous deposit. The corn lots do not excel others in this matter to the same extent as in the percent of fat laid down within the muscles. In both series the linseed oil meal lots rank either first or second as to percent of fat, either on the basis of the whole meat, or on the basis of the water-free meat.

The relative percentages of protein and fat, show that this was exceedingly fat meat, even though these hogs would have been called only about two-thirds fattened. The fat in the water-free meat varies between 75.82 percent in the "thin" shotes of the check lot and nearly 90 percent in several others.

The percentage of water in the fat-free meat of the corn lots, Nos. 1 and 7, was as in the tenderloins, very high; in these cross-sections it being decidedly higher than in other lots in both series, and hence reinforcing our previous observations in regard to this being a specific influence of the corn. Some other lots were fatter, and still others were not so fat, but in none of them was there so much water in the fat-free meat.

CONCLUSIONS FROM EXPERIMENT I.

In a comparison of corn alone, with corn supplemented by wheat middlings, linseed oil meal, soy beans, tankage and germ oil meal for full-feeding growing and fattening hogs,—all rations except the corn having the same nutritive ratio, namely 1:6.5,—as corn varied in cost between 40 and 60 cents per bushel, wheat middlings varied in value between $20 and $27 per ton, linseed oil meal between $38 and $57 per ton; soy beans between $41 and $61 per ton; tankage between $68 and $102 per ton, and germ oil meal between $20 and $30 per ton. (Table VII, p. 252.)

To yield a profit these supplements would have to be bought at prices lower than these valuations. The relative profits in the use of these supplements depends not only on the above "replacement values", but we must also consider the relative proportion of each in the balanced ration.

The six rations ranked as to palatability in the order in which the supplements are named:

1st.	Linseed oil meal.	4th.	Wheat middlings.
2nd.	Digester tankage.	5th.	Germ oil meal.
3rd.	Soy beans.	6th.	Corn alone.

Where hogs were full-fed on these rations, the middlings ration was 23 percent more efficient than corn alone, the linseed oil meal ration 32 percent, the soy bean ration 38.5 percent, the tankage ration 32.6 percent, and the germ oil meal ration 17.6 percent more efficient to cause gain in weight. (Table VI, page 250.)

Where these six rations were fed in practically equal but somewhat restricted amounts, the middlings ration was 28.9 percent more efficient than corn alone, the linseed oil meal ration 29.8 percent, the soy bean ration 22.6 percent, the tankage ration 18.1 percent, and the germ oil meal ration 16.4 percent more efficient than corn by itself.

The soy bean, tankage, and linseed oil meal rations produced equal gain in weight from the same expenditure of digestible nutriment; the wheat middlings, germ oil meal, and straight corn rations were much less efficient.

Linseed oil meal, tankage, and soy beans were both very efficient and very palatable as supplements to corn; middlings was efficient in the production of increased weight, but was much less palatable, while germ oil meal was neither efficient nor palatable, as compared with the other supplements.

The character of the increase produced by these rations was quite different. The tendency of five of these rations to cause growth of muscle and of internal organs was in the following order; wheat middlings, linseed oil meal, soy beans, tankage and corn alone. This was practically in accord with the phosphorus content of the rations; the tankage ration, however, failed to make growth in accord with its phosphorus content, probably because of the fact that its phosphorus was present mostly as bone. (Tables XI, XII, and XIII, pages 261 and 262.)

The tendency of these rations to fatten, as evidenced by the increase in the leaf-lard, was in the reverse order from that indicating tendency to cause growth.

The probability is that corn does not contain as much phosphorus as is necessary to the *maximum* muscular growth of which the animal is capable.

Corn alone caused a deposition of much more fat within the muscles, that is, between the fibers, than any other ration. (Table XIV, page 263.)

The tenderloin muscles of the corn-fed hogs contained less water than muscles from any other lot, but the percentage of water in the fat-free muscles of these corn-fed hogs was higher than in any other lot in the limited ration series, and exceeded only by the tankage lot in the full-fed series. The tankage ration was 92 percent corn.

In the meat of the cross-sections of the carcasses, the fat-free meat of the corn-fed hogs, in both series, contained decidedly more water than did any other lot, though the percentage of water in the meat as a whole was very low. (Table XV, page 265.)

The tenderloin muscles of the corn-fed hogs, in both series, were lower in protein than the muscles of any other lot. In the cross-sections the protein was also low.

The ash in the tenderloin muscles and cross-sections of the corn-fed hogs, in both series, was higher in the fat- and water-free meat than it was in the meat from the middlings, soy beans, and germ oil meal lots; and in two cases out of the four, was higher than in the tankage lots.

When compared with these more highly nitrogenous rations, corn by itself seems to produce smaller muscles which are peculiarly rich in fat; the moisture content of the meat as a whole is low, but the moisture in the fat-free meat is very high; the protein itself is low in amount, but the proportion of ash to protein is rather high.

The most striking peculiarity of the linseed oil meal ration is the high proportion of ash to protein in the meat produced by this feed.

TABLE XVI: PERCENTAGE COMPOSITION OF FOODSTUFFS USED IN EXPERIMENTS II AND III.

	Water	Nitrogen-free extract	Protein	Ether extract	Crude fiber	Ash	Calcium	Magnesium	Potassium	Sodium	Sulphur	Phosphorus	Chlorine
Corn	16 68	67.76	8.67	4.10	1 65	1.36	.009	.110	.280	.046	.141	.295	.040
Hominy....... ..	15.97	75 01	7.61	.86	.23	.36	.004	.018	.096	.011	.121	.049	.048
Blood flour........	11.44	......	82.50	1.00	......	3.04	.390	.068	.096	.370	.656	.210	.280
Bone meal.........	......	......	24.59	......	....	63.31	24.120	.530	.076	.548	.100	11 390	.041
Bran extract	92.58	4.95	1.40	.....	... ..	1.20	.018	.148	.253	.026	.037	.261	004

The germ oil meal ration occupied the opposite extreme from the linseed oil meal as regards the ash content of the tenderloin muscles, the percentage being lower than with any other lots.

In a number of lots there was less fat in the tenderloin muscles of the hogs which were fed for sixty days than there was in the muscles of the check lot, which was killed when the experiment began, and also in several lots there was an apparent loss of ash from the fat- and water-free meat during fattening. These facts are due to the hogs' being essentially corn-fed at the time the experiment began.

The increase in live-weight of the corn-fed hogs was more largely internal fat, and less largely muscles, than in any of the hogs which received higher-proteid ration. The hogs which received wheat middlings occupied the opposite extreme in this matter; their increased weight was more largely muscle, and less largely internal fat, than in any other lot. This comparison has an important bearing on the feeding of breeding animals, on whose reproductive efficiency excessive development of internal fat has an injurious effect, probably through restriction of circulation in the sexual organs, by the mechanical pressure of surrounding fat. (Table XI, page 261).

EXPERIMENTS II AND III

The general method of work was the same as in Experiment I. As in this series, five hogs were fed in each lot, one lot was killed at the beginning of each experiment, to serve as a basis for judgement as to changes produced by the experimental feeding, and a second lot was fed on corn alone, as a further basis for comparison.

The rations fed in these experiments were as follows:

EXPERIMENT II

Lot 1 Corn.
" 2 Hominy, blood-flour, bran-extract, (larger amount).
" 3 Hominy, blood-flour, lecithin.
" 4 Hominy, blood-flour, bran-extract, (smaller amount).
" 5 Hominy, blood-flour, bone-meal.
" 6 Hominy, blood-flour, sodium phosphate.
" 7 Check lot, killed at beginning of experiment.

EXPERIMENT III

Lot 1 Corn.
" 2 Check lot, killed at beginning of experiment.
" 3 Hominy, blood-flour, bran-extract.
" 4 Hominy, blood-flour, bone-meal.
" 5 Hominy, blood-flour.

TABLE XVII: DIGESTION COEFFICIENTS OF THE FOODSTUFFS USED IN EXPERIMENTS II AND III

	Protein Percent	Nitrogen-free extract Percent	Crude fiber Percent	Ether extract Percent
Corn	86	95	40	76
Hominy	86	95	40	76
Blood flour	62	....	..	100
Bran extract	76.2	86.2	..	...

TABLE XVIII: DIGESTIBLE NUTRIENTS PER HUNDREDWEIGHT OF FOODSTUFFS USED IN EXPERIMENTS II AND III

	Protein Pounds	Carbohydrates Pounds	Ether extract Pounds
Corn	7.456	65.032	3.116
Hominy	6.545	71.352	.654
Blood flour	51.150	......	1.00
Bran extract	1.067	4.267	.....

The digestion coefficients are, as in Experiment I, largely assumed, but the same basal ration was fed in each case, and hence if there is error in these coefficients it is the same in each lot, and does not affect comparisons.

The hominy is assumed to have the same digestion coefficients as the whole corn.

The blood-flour has been assigned the same coefficients as reported by Dietrich and König, (Composition and Digestibility of Cattle Foods, Vol. II).

The bran-extract is assigned the same coefficients as wheat middlings, as determined by Snyder of Minnesota.

In Experiments II and III we have considered the balance between the inorganic acids and bases in the rations fed. This appears to be a matter of much importance, at least as fundamental a one as the balance between proteids and non-proteid organic nutrients, the so-called nutritive ratio. (Table XIX, pages 271 and 272.)

The significance of this factor of mineral base and acid balance is discussed by the author in Ohio Bul. 207. Very briefly the facts are as follows: There are constantly being formed in the animal body, from the foods and from the tissues, inorganic acids which must be neutralized in order that the neutrality of the liquids and

TABLE XIX: AVERAGE DAILY NUTRIENTS PER HEAD. EXPERIMENT II.

Lot	Rations Grams	Digestible protein Grams	Digestible starch equivalent* Grams	Nutritive ratio	Calcium Grams	Magnesium Grams	Potassium Grams	Sodium Grams	Sulphur Grams	Phosphorus Grams	Chlorine Grams	Excess normal acid C. C.
1	Corn.................. 2114.2	157.6	1532.7	1 : 9.73	.199	2.326	5.920	.973	2.981	6.237	.846	217.90
2	Hominy.................... 1991.8 Blood-flour.................. 165.6 Bran extract, (larger amt.) 2039.4	236.7	1543.1	1 : 6.52	1.092	3.500	7.239	1.358	4.236	6.641	1.491	149.11
3	Hominy.................... 2068.9 Blood-flour.................. 187.3 Lecithin.................... 4.00	231.2	1512.8	1 : 6.54	.822	.504	2.166	.921	3.728	1.562	1.518	198.50
4	Hominy.................... 2074.3 Blood-flour.................. 181.4 Bran-extract,(smaller amt.) 779.3	236.8	1550.4	1 : 6.55	.936	1.675	4.140	1.100	3.980	3.429	1.531	176.50
5	Hominy.................... 1821.2 Blood-flour.................. 162.4 Bone-meal.................... 20.9	202.3	1331.8	1 : 6.58	5.747	.552	1.920	.915	3.286	3.610	1.337	54.91
6	Hominy.................... 2068.4 Blood-flour.................. 187.3 Sodium phosphate.......... 1.8	231.2	1512.8	1 : 6.54	.822	.504	2.166	1.152	3.728	1.562	1.518	188.48

* Nitrogen-free extract and ether extract.

TABLE XIX: AVERAGE DAILY NUTRIENTS PER HEAD. EXPE RIMENT III. Concluded.

Lot	Rations		Digestible protein	Digestible starch equivalent*	Nutritive ratio	Calcium	Magnesium	Potassium	Sodium	Sulphur	Phosphorus	Chlorine	Excess normal acid
		Grams	Grams	Grams		Grams	Grams	Grams	Grams	Grams	Grams	Grams	C. C.
1	Corn	1426.9	106 5	846 4	1 : 9.73	.134	1.571	3.998	.657	2.013	4.212	.571	147.14
3	Hominy Blood-flour Bran-extract	1548.6 171.9 589.7	195 6	1158.5	1 : 5 92	.842	1 272	3 144	.958	3 214	2.655	1.245	138.63
4	Hominy Blood-flour Bone-flour	1570.4 174.6 11.0	191.9	1149.4	1 : 5 98	3 406	.463	1.684	.879	3 054	2.390	1 247	90.86
5	Hominy Blood-flour	1286 9 143.3	157 9	945.1	1 : 5.98	.616	.332	1.378	.672	2 500	0 934	1 021	122.70

* Nitrogen-free extract and ether extract.

tissues may be maintained and the continuance of life thus rendered possible. The basic minerals in foods contribute to one side of this account, and the acid minerals to the other. An amount of acid mineral elements in the food in excess of the animal's capacity to neutralize them in normal ways may cause a withdrawal of basic minerals from the body, and, in consequence, most serious disturbances of nutrition.

The basic mineral elements considered in this connection are calcium, magnesium, potassium, and sodium; the acid minerals, sulphur, phosphorus, and chlorine.

In determining this balance between basic and acid minerals, we compute each to cubic centimeters of normal solution; that is, so that one cubic centimeter of any base will exactly neutralize one cubic centimeter of solution of any of the acid elements. Phosphoric acid is considered to be neutralized when two of its hydrogen atoms are replaced.

A peculiar relationship between the actions of calcium and magnesium in the body requires that a definite proportion between the quantities present in its liquids be maintained. They appear to be antagonistic, and an excess of magnesium occasions the liberation of calcium in quantity sufficient to counteract the effects of this excess of magnesium. The excess of both is then excreted. Thus an excess of magnesium, in proportion to calcium, may cause, just as may acid mineral elements, a withdrawal of calcium from the body, and pathological consequences such as usually result only from an excess of acids.

In Experiments II and III the rations are all characterized by an excess of mineral acid over mineral base.

The only differences of moment in this regard among the rations are in the somewhat lower excess of acid in the bone meal lot than in others, and the considerably greater excess of acid in corn than in the mixed rations. The corn ration besides having the most acid ash, has the least calcium, sodium, chlorine and sulphur, and the most magnesium, potassium and phosphorus, and the smallest proportion of proteid to non-proteid organic nutrients.

Experiment II. The hogs used in this experiment weighed about 125 pounds each; were mostly grade Poland Chinas of common quality; were six months old, in stock condition, and had been raised on corn and grass. The preliminary feeding occupied two weeks' time. The experiment was conducted during April and May of 1906.

In this test we sought to learn how a lack of phosphorus affects (1) the development of swine, and (2) the composition of their tissues; and (3) to compare bone meal, water extract of wheat bran, sodium phosphate and lecithin as sources of phosphorus for growing pigs. In this experiment we consider the nutritive values of two organic phosphorus compounds, phytin, the principal phosphorus compound in the bran-extract, and lecithin; and two inorganic compounds, sodium phosphate, and calcium phosphate, as found in bone meal.

The distinction between organic and inorganic phosphorus compounds is largely arbitrary, and not always satisfactory, since inorganic salts of phosphoric acid, may enter into combination with organic compounds, and thus become organic phosphorus, without the agency of any vital process. Hence this distinction is not clean-cut and consistent. There is, however, a general dissimilarity between organic and inorganic phosphorus compounds, using the terms in the usual signification, and also a marked distinction in the nutritive values of these two groups. The usefulness of the distinction appears to outweigh its inaccuracies.

As a standard basal ration we adopted pearl hominy and blood-flour, which contained 82.5 percent of protein and only two-tenths of one percent of phosphorus. The hominy consists of the corn kernel minus the bran, or skin, and the germ, and is very much lower than corn in fat, fiber and ash constituents. These feeds furnished us a cheap and palatable balanced ration which was very low in phosphorus, and constituted a satisfactory basal ration for our comparisons. In subsequent work we have used blood albumen and wheat gluten as proteid supplements. They contain still less phosphorus than does blood flour.

In this experiment Lot 1 received corn alone; Lots 2 and 4 received different amounts of water-extract of wheat bran with their basal ration of hominy and blood-flour. This extract was prepared by soaking bran in luke-warm water, from one feeding period until the next, the hogs being fed twice daily. Two quarts of water were used in soaking each pound of bran. At feeding time the mash was put into a sack of thick cloth, and a cider press was found to be a quick and easy means of expressing the liquid. The feed, which in all lots was fed finely ground, was made into a moderately thick slop, either with the bran extract or with water. The extract was analyzed, and a correction was made in the basal ration for the two lots receiving it, so that the nutritive ratio might be the same in all cases, except with the corn lot. This bran extract was exceedingly rich in magnesium, potassium and phosphorus. The phosphorus was present mostly as phytin, a salt formed by the union of calcium, magnesium and potassium with phytic acid, a complex, organic, phosphoric acid which constitutes a large proportion of the phosphorus compounds of seeds. Where bacterial fermentation was considerable during the preparation of the extract, the magnesium and phosphorus contents were more than twice as great as when sterile utensils and water were used, but in both cases the relation of total mineral bases to mineral acids was practically the same. The extract was in this regard about neutral.

Lot 3 consisted of but a single hog, the cost of lecithin making it impracticable to feed more. Four grams per day were fed to this hog, the lecithin being provided by Dr. W. Koch, of the Department of Physiology. The material was emulsified in water and added to the hominy and blood-flour. When it is considered that this lecithin contained but 3.883 percent of phosphorus it is apparent that the total amount fed did not provide any considerable quantity of this element. It was used with the hope of learning of its function in nutrition. It is a universal cell constituent of plants and animals, but does not constitute a large proportion of the total phosphorus of foods.

Lot 6 received with its basal ration just enough di-sodium phosphate to furnish to each pig the same amount of phosphorus as was received in lecithin by the pig in Lot 3. We refer to Lot 6 as the "low-phosphorus" lot.

In Lot 5, raw bone-meal was fed mixed with the ration. The bone-meal contained nitrogen equivalent to 24.59 percent of protein, but as this was doubtless present mostly as collagen, a substance of low food value, and the total amount of bone fed was only 13 pounds, no account of this protein was taken in the compounding of the rations. The phosphorus of this foodstuff was present mostly as tri-calcium phosphate.

Salt was given apart from the feed in each lot.

This experiment lasted 56 days.

It was hoped that all of the lots might be kept together in the amount of feed consumed but the rations were peculiar and it was soon apparent that each one would have to be fed with reference alone to the pigs consuming it.

With Lot 2 we attempted to find the amount of bran-extract that could be fed. It seems to be easy to overfeed with it, the pigs being willing to take much more of it than is beneficial to them. These pigs would cease eating before having cleaned up the feed well; appeared uneasy, coughed, gritted the teeth and allowed much saliva to drip from the mouth. Their joints became sore and swollen, and they moved around with reluctance and difficulty. These symptoms and other evidences of discomfort largely disappeared after the amount of bran-extract was cut down.

Lot 4, receiving less bran-extract, ate heartily and consistently at all times, and we must base our conclusions as to the effects of bran-extract as a food on the record of this lot. The amount of bran-extract fed to this lot was regarded as very satisfactory. The average amount fed was one pound to 2.89 pounds of dry feed. Probably a much greater amount could have been fed had we used chalk with the bran-extract to protect the pigs from the effects of the excessive amount of magnesium present.

The bone-meal lot was hard to feed. These hogs frequently went off feed, apparently because of the bone-meal, and on this account the total amount of feed eaten was smaller than in any other lot. We succeeded much better in feeding this bone-meal after grinding it to a fine flour in a pebble mill. This, however, had to be learned by experience.

The lecithin pig, Lot 3, was always ravenous for his feed and his ration was clearly more palatable than any other used in the experiment.

The other low-phosphorus lot, No. 6, also ate well. These two lots, Nos. 3 and 6, and No. 4, which received the smaller amount of bran-extract, were never fed up to their full capacity.

Lot 1, which received corn alone, ate consistently throughout the experiment; doing very well indeed for pigs so fed. Their record was unusually creditable to corn alone as a hog feed. This is, of course, largely due to the shortness of the experiment. They were fed as much as they would eat but did not consume as much feed as the other lots which were not fed to the limit of their appetites.

These rations affected the digestive system very differently. The corn ration was much the most laxative in its action. The ration of hominy and blood-flour was very constipating, most so in Lots 3 and 6, receiving lecithin and sodium phosphate, respectively, and least so in Lots 2 and 4, receiving bran-extract. The bone-meal lot was usually constipated, but sometimes scoured. This lot had rough coats, and did not shed off well. They did not like bone-meal fed mixed with the feed. The constipating character of the basal ration is doubtless due to its low contents of fibrous material and mineral matter.

Experiment III, conducted during October, November and December, 1906, was a repetition of Experiment II, except that the lecithin lot, and the lot receiving the larger amount of bran-extract were omitted, and no sodium phosphate was fed to the low-phosphorus lot.

The facts that the bone-meal lot in Experiment II was not in entirely normal state of nutrition, and did not make as large gains in weight as those lots with which we wished to compare it, rendered close comparisons of results a little doubtful. Hence it seemed desirable to repeat this work. In Experiment III, as will be seen by Table XIX, page 272, the bone-flour lot, No. 4, ate more feed than the low-phosphorus lot, No. 5, and practically as much as the bran-extract lot. This gives us a better basis for judgment as to the capacities of the bone-meal ration.

The pigs on which Experiment III was conducted were much superior to those used in the previous experiments. They were four-months-old, pure-bred Duroc Jerseys; they were all sired by the same boar; their dams were all by the same boar, and their grand-dams were closely related; further than this, they had been raised from birth together. These were growing pigs rather than growing and fattening hogs, as in the previous experiments.

The method followed was the same as in the previous experiment, except that the bran-extract was fed in the proportion of 150 cubic centimeters of the extract to each pound of dry feed given. This is the equivalent of a quart of the extract to 6.31 pounds of feed. This lot of pigs was in the best of health throughout the experiment.

The bone-meal was reduced to a fine flour, and fed in this condition from the beginning. We did not experience difficulty in the feeding of the bone in this shape.

The corn ration was not so well relished by these pigs as by the older ones in Experiment II, (Table XIX, page 271), and though these pigs were three months younger and of decidedly better quality, the gains were much more expensive. The younger the pig the less nearly a perfect feed is corn by itself.

With these young pigs there is also a much greater difference between the bran-extract and the low-phosphorus lots in favor of the former; that is, the lack of the ash constituents in the hominy and blood-flour ration was much more keenly felt by the young pigs in this experiment than by the older and larger ones of Experiment II, the younger ones having a less extensive reserve supply of the ash constituents on which to draw to make good the deficiencies of the ration.

As in the previous experiment the bran-extract proved to be slightly laxative, and the hominy and blood-flour without the addition of this supplement, very constipating.

The bran-extract lot ate their food with the keenest relish, though not particularly more so than the bone-flour lot. The low-phosphorus lot did not eat very heartily, and their rough, dead-looking coats gave them an unthrifty look. The corn lot had the poorest appetites of all, and looked the most poorly nourished.

The largest pig in the corn lot was taken out of the experiment, being rendered unfit by an accidental injury. This leaves average weights light in this lot.

TABLE XX: FEEDS AND GAINS IN WEIGHT.

EXPERIMENT II.

Lots	Rations	Digestible nutriment per 100 lbs. gain Lbs.	Ave. initial weight Lbs.	Ave. final weight Lbs.	Number of pigs in lot
1	Corn	364.9	125	182.2	5
2	Hominy; blood-flour; bran-extract, (larger amount)	298.6	126.8	200.4	5
3	Hominy; blood-flour; lecithin	231.5	127	220	1
4	Hominy; blood-flour; bran-extract, (smaller amount)	271.7	124	205.2	5
5	Hominy; blood-flour; bone-meal	295.0	126.6	190.8	5
6	Hominy; blood-flour; sodium phosphate	272.5	124.8	203.8	5
7	Check lot; killed		125 2		5
		EXPERIMENT III			
1	Corn meal	554.2	67	94.25	4
2	Check lot; killed	....	78.6	.....	5
3	Hominy; blood-flour bran-extract	330.5	78.4	132.6	5
4	Hominy; blood-flour bone-flour	365.0	79.6	128.2	5
5	Hominy; blood-flour	447.5	78.4	111.0	5

Length of Experiment II, 56 days; of Experiment III, 60 days.

Experiment II. Lot 2, where the bran-extract was fed in the excessive amount, did not make as economical gains in weight as Lot 6, the low-phosphorus lot. Lot 5, the bone-meal lot, also failed to make as economical gains as the low-phosphorus lot. The excess of magnesium in ration No. 2, and the depressing effect of the bone-meal on the digestibility of protein in ration No. 5 are at least in part responsible for the poor showing made by these rations; for Lot 4, with the lower amount of bran-extract, used it to advantage, and made as efficient gains in weight as did Lot 6, the low-phosphorus lot; that it did not make more economical gains in weight, appears to be due to the shortness of the experiment. As is well known, an animal may for considerable periods of time give off more phosphorus in the urine and feces than is present in the food. The effects of phosphorus starvation are not immediately manifest. There are reserves of phosphorus in the body which may be used to supplement a ration which is lacking in this element. This table however, gives no hint as to the character of the increase. It is here that we must hope to find more significant results.

It is apparent, nevertheless, that these various balanced rations, however artificial their character, were all decidedly more efficient than corn alone. The low-phosphorus lot withstood a temporary lack of ash constituents to much better advantage than the corn lot withstood the lack of protein.

Regarding Lot 3, the lecithin pig, we publish these results because we do not wish to suppress any of the evidence, whatever its trend, but the results from a single individual are not fairly comparable with an average of results from five. This evidence is not entirely without weight, however, and so far as it goes is favorable to the belief that lecithin is a valuable nutrient.

Experiment III. The amounts of digestible nutriment eaten per hundred pounds of gain in weight were consistent with the character of the rations. The bran-extract lot received most nearly a normal ration. This lot made the most efficient gains. The bone-flour lot ranked next, it being apparent that, in the amounts fed, this supplement was less efficient than bran-extract to furnish what was lacking in the hominy and blood-flour ration.

The hominy and blood-flour ration, containing an abundance of easily digestible protein and starch, and being in a palatable form, was still decidedly lacking in some constituents necessary to the nourishment of growing pigs.

The ration of corn alone contained less protein, but more of the ash constituents, and was still less efficient than the ration of hominy and blood-flour. In both Experiments II and III the corn ration was the highest in phosphorus and lowest in calcium and in protein.

Experiment II, (Table XXI page 281). The killing of these hogs was conducted at a local slaughter house. The cross-section, instead of being taken at the sixth rib, as in Experiment I, consisted of a three-rib cut taken just behind the shoulder. The thickness of the back-fat was measured on the rear aspect of this section. Samples of the liver and kidney as well as the tenderloin were prepared for analysis, but the chemical study of the cross-section was discontinued, our judgment as to the fatness of the animals being based on the relation of dressed to live-weight, the weight of the leaf-lard, the thickness of the back-fat, and the analyses of the tenderloins.

At the time of killing, the hogs in the six lots fed would have graded as to condition in the market, as follows:

Lot 1. 1 choice, 1 good, 3 medium, (corn alone).
" 2. 3 choice, 1 good, 1 medium, (larger amount of bran-extract).
" 3. 1 good, (lecithin).
" 4. 4 choice, 1 medium, (smaller amount of bran-extract).
" 5. 1 choice, 1 good, 2 medium, 1 common, (bone-meal).
" 6. 2 choice, 2 good, 1 medium, (low phosphorus ration).

Three lots of these hogs increased the thickness of the back-fat from one inch to more than two inches in fifty-six days, but none of them doubled the weight of the tenderloin muscles. The leaf-lard and the kidneys also increased rapidly in weight, much more so than the lungs, spleen, heart and liver.

Experiment III. At the time these shotes were killed, the pigs in the four lots averaged in weight between 94.25 and 132.6 pounds; the pigs in the check lot, killed when the experiment began, weighing 78.6 pounds each.

Judging these pigs by the fat-hog standard of the market they would have graded as follows: The corn lot, and the hominy and blood-flour lot, "common"; the bran-extract lot, 1 "choice", 3 "good", 1 "common"; and the bone-flour lot, "good". This last was clearly the fattest lot.

The bran-extract lot, having gained the most in weight, excelled all the other lots in the development of each of the parts observed except that the bone-flour lot excelled it in thickness of back-fat and in weight of leaf-lard, the apparent fatness of these hogs when alive being borne out by the examination of the carcasses.

TABLE XXI: SLAUGHTER RECORDS. AVERAGE WEIGHT OF PARTS.

EXPERIMENT II.

Lots	Rations	Gross dressed weight	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loins	Thickness of back-fat
		Pounds	Ounces	Pounds	Ounces	Pounds	Pounds	Ounces	Grams	Inches
1	Corn..........	137.33	8.30	2.73	3.20	1.80	5.88	6.03	262.2	1.89
2	Hominy; blood-flour; bran-extract, (larger amount)...	158.87	9.15	3.57	3.93	1.84	5.47	10.53	336.8	2.10
3	Hominy; blood-flour; lecithin....	165.69	10.63	3.66	4.00	1.43	7.19	8.00	374.0	1.75
4	Hominy; blood-flour; bran-extract, (smaller amount)....	159.81	9.4	3.08	3.13	2.03	6.61	8.75	357.4	2.08
5	Hominy; blood-flour; bone-meal......	146.49	8.53	3.26	3.16	1.39	5.49	9.18	302.8	1.83
6	Hominy; blood-flour; sodium phosphate.......	160.72	8.88	3.40	3.33	1.81	6.22	8.95	330.6	2.16
7	Check lot..	92.30	6.46	2.49	2.34	1.33	3.71	4.40	201.6	1.02

EXPERIMENT III.

Lots	Rations	Gross dressed weight	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loins	Thickness of back-fat
1	Corn	66.9	4.49	1.77	1.25	1.55	3.58	3.83	121.1	1.46
2	Check lot..	51.45	4.50	1.83	1.43	.88	1.16	4.25	134.1	1.05
3	Hominy; blood-flour; bran-extract...........	96.4	6.75	2.72	2.06	1.60	4.21	7.75	208.9	1.52
4	Hominy; blood-flour; bone-flour........	92.7	6.17	2.54	1.62	1.51	4.59	6.05	188.7	1.59
5	Hominy; blood-flour.........................	79.1	5.90	2.06	2.04	1.53	3.29	6.05	174.0	1.50

TABLE XXII: RELATION OF PARTS TO DRESSED CARCASS

EXPERIMENT II

Lots	Rations	Percent gross dressed to live weight	Per-cent of heart	Per-cent of liver	Per-cent of spleen	Per-cent of lungs	Per-cent of leaf-lard	Per-cent of kid-neys	Per-cent of tender-loins
1	Corn.....	75.37	.378	1.988	.146	1.311	4.28	.275	.421
2	Hominy; blood-flour; bran-extract, (larger amount)	79.28	.360	2.247	.155	1.158	2.44	.414	.467
3	Hominy; blood-flour; lecithin	75.31	.401	2.209	.151	.863	4.34	.302	.498
4	Check lot	77.88	.368	1.927	.122	1.270	4.14	.342	.493
5	Hominy; blood-flour; sodium phosphate	76.78	.364	2.225	.135	.949	3.75	.392	.455
6	Hominy; blood-flour; bone-flour	78.86	.345	2.115	.129	1.126	3.87	.348	.453
7	Hominy; blood-flour; bran extract, (smaller amount	73.84	.437	2.698	.158	1.441	4.02	.298	.482
	EXPERIMENT III								
1	Corn.........	71.0	.420	2.64	.012	2.32	5.35	.359	.399
2	Check lot......	66.5	.547	3.55	.017	1.71	2.25	.516	.575
3	Hominy; blood-flour; bran-extract	72.7	.438	2.82	.013	1.66	4.37	.502	.478
4	Hominy; blood-flour; bone-flour	72.3	.416	2.74	.011	1.63	4.95	.410	.449
5	Hominy; blood-flour	71.3	.466	2.60	.016	9.31	4.16	.480	.485

Lot 1, in Experiment III, fed on corn alone, contained but four pigs, one of the original five, the largest, having been removed early in the experiment because of a mechanical injury; the other lots contained five pigs each.

Experiment II. The low-phosphorus lot, No. 6, (see above table), dressed a high percentage of carcass to live-weight and, as will be seen in Table XXI, page 281, had the thickest back-fat.

The corn lot dressed a low percentage of carcass to live-weight, on account of the small amount of increase put onto the carcass, though as a rule corn produces a carcass which, because of small viscera and thick fat, dresses out a high percentage of carcass to live-weight. This lot was low in percentage of tenderloin and high in percent of leaf-lard.

The lungs of the corn lot were heavier in proportion to the carcass, and the kidneys were lighter, than in any other lot.

It will be noted that the check lot had a larger percentage of heart, liver, spleen, and lungs than any of the lots that were fed, but the kidneys of the lots which received the balanced rations were heavier in comparison with the weight of the carcass than in the check lot; this doubtless being due to the protein in these rations, for the corn lot and this one only, did not increase its percentage of kidneys during the course of the experiment.

Experiment III. These lots of hogs each dressed about the same percentage of carcass to live-weight. The bran-extract lot exceeded the bone-flour lot, even though not so fat. It would seem that the excess of muscle in the bran-extract lot more than offset the excess of fat in the bone-flour lot. The corn lot, and the hominy and blood-flour lot, which received the low-protein and the low-phosphorus rations respectively dressed the lowest percentages of carcass to live-weight, since neither of these rations was well adapted to the production of growth.

The carcasses of the corn-fed hogs contained the largest percent of leaf-lard and lungs, and the smallest percent of kidneys and tenderloin muscles.

Experiment II, (Table XXIII, page 284). The percent of gain in the live-weight was about the same in Lots 4 and 6, the bran-extract and the low-phosphorus lots. Both of these gained decidedly more rapidly than did the corn lot, No. 1. Even the difficulty which we had with the feeding of bone-meal to Lot 5 did not prevent this lot from exceeding the corn lot in increased weight. The hearts, livers, kidneys and tenderloin muscles of these corn-fed pigs gained very poorly. This lot gained fairly well, however, in thickness of back-fat and in weight of leaf-lard.

It is worthy of note that the bone-meal lot, No. 5, while gaining 51 percent in live-weight, gained 105 percent in the ash of the bones and 48.5 percent in the weight of the muscles. This lot and the corn lot were the only ones which did not gain in muscle as fast as in live-weight.

Experiment III. The corn lot seems to have gained the least in live-weight, liver, spleen, kidneys and tenderloin muscles, but the loss of one pig renders the figures with reference to this lot of slightly uncertain value.

The bran-extract lot excelled the bone-flour and the low-phosphorus lots in percentage of gain in live-weight, heart, liver, spleen, lungs, kidneys and tenderloin mucles.

The bone-flour lot, however, excelled in the percentage of increase in leaf-lard, thickness of back-fat, and in the ash of the bones. This lot ate practically as much feed as the bran-extract lot, but probably because of the unavailability of bone phosphates for muscular growth, the digested nutriment was laid down as fat rather than as proteid increase.

The hominy and blood-flour, or low-phosphorus lot, was at a conspicuous disadvantage, as compared with the bran-extract and the bone-flour lots, in the formation of bone, the ration providing very little indeed that the pigs seem to have been able to use for this purpose. The ability of this lot to lay on fat and muscle was not hindered to nearly so great an extent as was its ability to grow bone.

TABLE XXIII: PERCENT OF INCREASE IN WEIGHTS AND MEASUREMENTS OF PARTS.

EXPERIMENT II

Lots	Rations	Live weight	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loins	Thickness of back-fat	Ash of humerus
1	Corn...	45.76	28.68	8.64	36.7	35.3	58.9	37.4	30.25	85.3	44.7
2	Hominy; blood-flour; bran-extract, (larger amount..	58.04	39 9	41.7	65.8	36.3	45.5	136.1	64.93	104.0	44.3
3	Hominy; blood-flour; lecithin..................	73 23	62.3	44.7	68.8	6.0	91.0	79.4	82.89	70.0	68.6
4	Hominy; blood-flour; bran-extract, (smaller amount..................................	65.48	46 9	24.7	34.9	53.8	80.1	100.7	78.97	106.0	61.2
5	Hominy; blood-flour; bone-meal	50.71	30.6	29.4	33.3	3.0	46.3	106 3	48.50	77 7	104.9
6	Hominy; blood-flour; sodium phosphate......	63.30	37 9	37 1	42 9	36.1	68.1	103.9	64 48	111.8	56.6
	EXPERIMENT III										
1	Corn*..............................	40.7	19.7	12.5	-9.1	108.9	224.3	-2.3	7.36		41.6
3	Hominy; blood-flour; bran-extract...........	69 1	50.0	49.0	44.6	81.8	262.9	82.4	55.8	44.3	40.5
4	Hominy; blood-flour; bone-flour...............	61.0	35.3	37.4	12.3	69 7	292.3	40 8	37.0	50.0	43.6
5	Hominy; blood-flour.................	41.6	31.1	12.9	43.2	73 9	183.6	42 4	29 8	43.2	3.2

* Computed with reference to four of the pigs of the check lot.

TABLE XXIV: INCREASE IN WEIGHT OF VARIOUS PARTS AND ORGANS IN RELATION TO GAIN IN LIVE-WEIGHT.

EXPERIMENT II.

Lots	Rations	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loin	Thickness of back-fat	Ash of humerus
1	Corn.....	.627	.211	.802	.771	1.287	.817	.661	1.864	.977
2	Hominy; blood-flour; bran-extract, (larger amount).....................	.687	.718	1.134	.625	.784	2.345	1.119	1.792	.763
3	Hominy; blood-flour; lecithin	.851	.610	.939	.082	1.243	1.084	1.132	.956	.937
4	Hominy; blood-flour; bran-extract, (smaller amount)....................	.716	.377	.533	.822	1.223	1.538	1 206	1 619	.935
5	Hominy; blood-flour; bone-meal.......	.603	.580	.657	.059	.913	2 096	.956	1.532	2.069
6	Hominy; blood-flour; sodium phosphate.........	.599	.586	.678	.570	1.076	1.641	1.019	1.766	.894

EXPERIMENT III.

Lots	Rations	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loin	Thickness of back-fat	Ash of humerus
1	Corn...........	.484	.307	—.224	2.675	5.511	—.057	.181	1.516	1.022
3	Hominy; blood-flour; bran-extract...	.724	.709	.645	1.184	3 805	1 192	.808	.641	.586
4	Hominy; blood-flour; bone-flour.......	.580	.613	.202	1.143	4.792	.667	.607	.820	.715
5	Hominy; blood-flour............	.748	.310	1 039	1.776	4.413	1.019	.716	1.039	.077

Experiment II. The most significant data of the experiment are set forth in the preceding table. The large increase in the weight of the leaf-lard and in the thickness of the back-fat indicate a large percentage of fat in the increase of live-weight, the corn lot naturally leading in these regards, and being last in gain of muscle. This lot also gained very little in weight of liver and kidneys, in relation to gain in live-weight.

The increase in the low-phosphorus lot, No. 6, greatly exceeds the corn lot in percent of liver, kidneys and tenderloin muscles. The lack of protein and calcium in the corn seems to have been more severely felt than the lack of phosphorus and potassium in the low-phosphorus ration.

The increase in the bran-extract lot, No. 4, was higher in percent of heart, lungs, leaf-lard and tenderloin muscles than in the low-phosphorus lot. The rations being otherwise the same, it must be concluded that the bran-extract furnished valuable nutrients which were lacking in the low-phosphorus ration, these probably being phosphorus and potassium.

In the bone-meal lot the gain in weight was less largely muscle than in the low-phosphorus lot, while at the same time the proportion of bone-ash in the increased weight seems to have been three times as great. The addition of bone-meal to the ration appears not to have added to its tendency to produce muscle.

The bran-extract, however, did cause an improvement in the hominy and blood-flour ration, as regards both bone and muscle formation. Bran-extract seems to have a capacity that bone-meal does not to take part in proteid increase.

Experiment III. The bone-flour lot produced a smaller proportion of muscle in the increase in weight than the low-phosphorus lot, the rations differing only with regard to the presence of the bone-flour. Obviously the composition of the increase is not rendered more largely muscle because of the addition of bone-flour to the hominy and blood-flour ration. The bran-extract ration, however, produced a decidedly greater proportion of muscle in the increase than did any other lot. We incline to ascribe this difference in the usefulness of these supplements most largely to the differences in the compounds of phosphorus contained in them.

The corn ration, with its deficiency of protein, produced a much smaller proportion of muscle in the increase than did any other ration.

The proportion of bone-ash in the increase was greater with the corn lot than with the bone-flour lot. The corn lot received more phosphorus than any of the other lots in this experiment. The low-phosphorus ration made peculiarly little increase in the ash of the bone, and the addition of bran-extract to this ration was of decided benefit in the deposit of ash in the bones.

The two lots which produced the greatest proportion of back-fat in the increase are the corn, and the low-phosphorus lots, these being the most abnormal rations, and those in which a lack either of protein, or of ash constituents, was disadvantageous to the construction of bone and muscle.

The slightly smaller proportion of muscle in the increase in the bone-flour lots, than in the low-phosphorus lots, in both these experiments, gives evidence of the depressing effect which calcium phosphate has on the digestibility of protein.

Experiment II, (Table XXV, page 288). The bones of the bone-meal lot, No. 5, were larger than in other lots, as is evidenced by their volume; the amount of ash was also greater; the ash per cubic centimeter of volume was greater, and the breaking strength greater than in other lots. Clearly bone-meal in the ration contributes to the nourishment of the bones, even though it appears not to be useful in muscle building.

The lack of protein in corn tends to reduce the size, density and strength of the bones, as is seen by comparing Lots 1 and 6, the latter containing more protein, but less ash, than the former.

Experiment III. The volume of the bones in the different lots differed but little. The smallness of the bones of the corn lot was partially due to the fact that the largest pig had been removed from this lot.

The bone-flour ration did not produce as large bones as the bran-extract ration, though the ash per cubic centimeter of volume was much greater; that is, the bone was denser. The bone produced by the low-phosphorus ration was less dense than any other.

The density of the bone of the corn, and the bone-flour lots was about alike.

The breaking strength was least with the low-phosphorus lot while the bran-extract, and bone-flour lots both ranked higher than the corn lot. It should be borne in mind that the bone-flour lot in this experiment received much less phosphorus than did the corn lot, but its greater amount of calcium appears to have been of benefit in the production of strong bone.

TABLE XXV: DATA CONCERNING DEVELOPMENT OF BONES

EXPERIMENT II.

Lots	Rations	Volume of each humerus C. C.	Ash in each humerus Grams	Ash per c. c. Grams	Breaking strength Lbs.	Length Cm.	Longer transverse diameter Cm.	Shorter transverse diameter Cm.
1	Corn.............	108.0	32.92	.3048	509	13.88	2.25	1.63
2	Hominy; blood-flour; bran-extract, (larger amount).....	111.8	33.33	.2981	575	13.68	2.23	1.67
3	Hominy; blood-flour; lecithin.....	118 0	38 97	.3303	736	13.70	2.20	1.66
4	Hominy; blood-flour; bran-extract, (smaller amount).................	117.6	36.39	.3094	676	13.74	2.34	1.68
5	Hominy; blood-flour; bone-meal.	121.3	46.22	.3811	791	14.00	2.28	1.71
6	Hominy; blood-flour; sodium phosphate......	112.5	35.59	.3164	624	13.90	2.33	1.69
7	Check lot.......................................	78.9*	22.80*	.2890*				

EXPERIMENT III.

Lots	Rations	Volume of each humerus C. C.	Ash in each humerus Grams	Ash per c. c. Grams	Breaking strength Lbs.	Length Cm.	Longer transverse diameter Cm.	Shorter transverse diameter Cm.
1	Corn;..................	74.6	23.82	.319	502	13.1	1.83	1.37
2	Check lot.....	65.9	19.93	.3024	440	11.64	1.75	1.30
3	Hominy; blood-flour; bran-extract.............	100.1	28.01	.280	641	14.46	1.98	1.51
4	Hominy; blood-flour; bone-flour................	94 4	28.97	.307	606	13.46	2.08	1.46
5	Hominy; blood-flour.................... . .	93.7	20.56	.219	426	13.56	1.95	1.41

*Computed as a basis for reckoning increase made in other lots.

TABLE XXVI: ANALYSES OF TENDERLOIN MUSCLES

EXPERIMENT II

Lot	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	73.51	19.73	5.17	1.09	.264	77.52	19.52	1.34	5.52	24.22
2	Hominy; blood-flour; bran-extract, (larger amount)	73.62	18.85	5.17	1.13	.195	77.63	19.60	1.04	6.00	17.35
3	Hominy; blood-flour; lecithin	74.63	15.78	4.27	1.10	.352	77.97	16.83	2.23	6.98	32.00
4	Hominy; blood-flour; bran-extract, (smaller amount)	72.74	20.67	4.22	1.21	.252	75.10	15.48	1.22	5.85	20.83
5	Hominy; blood-flour; bone-meal	72.83	20.13	5.12	1.08	.233	76.77	18.85	1.16	5.37	21.57
6	Hominy; blood-flour; sodium phosphate	72.87	20.74	5.14	1.10	.264	76.82	18.95	1.27	5.30	24.00
7	Check lot	73 57	18.53	4 97	1.10	.247	77.42	18.80	1.33	5.93	22.45

EXPERIMENT III

Lot	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
1	Corn	73.39	17.68	6.16	1.07	.228	78 21	23.15	1.29	6.05	21.31
2	Check lot	76.35	19.42	3.04	1.13	.238	78.74	12.85	1.23	5.30	21.06
3	Hominy; blood-flour; bran-extract	73.74	21.85	3.90	1.03	.195	76.73	14.85	.81	4.71	18.93
4	Hominy; blood-flour; bone-flour	73.20	18.30	4.46	1.12	.222	76.62	16.64	1.21	6.12	19.82
5	Hominy; blood-flour	72.81	20.39	4.52	1.15	.228	76.26	16.62	1.12	5.64	19.83

The analyses of the muscles, livers and kidneys involved much work which does not yield results of immediate practical value. These data, however, will assist us in learning how these tissues and organs vary in composition, and in some cases probable causes and interesting associations of factors are observed. After a sufficient accumulation of evidence we shall be able to say just how foods vary the composition of animals, and to interpret and apply the results in a practical way; but we must establish the facts before attempting to draw conclusions.

The tenderloin muscles produced by Lot 1, the corn lot, in Experiment II, (Table XXVI, page 289), were characterized as in Experiments I and III by their high fat and low protein content, and by the high water-content of the fat-free meat.

In Experiment II there is more phosphorus in the muscles of the corn-fed lot, in the meat as a whole, and in the protein, than in the check lot, No. 7, which was not fed.

In Experiment III, however, the condition is reversed; in the corn lot, No. 1, there being less phosphorus in the meat as a whole, and in the protein, than in the check lot, No. 2. This is partially due to the greater age of the pigs in Experiment II. They throve to much better advantage on corn alone than did the younger pigs in Experiment III. Further, the check lot in Experiment III had been raised on foods containing more phosphorus than those on which the check lot in Experiment II had been raised.

The low-proteid, high-phosphorus character of the corn ration, as compared with these others, shows itself in the composition of the muscles.

In both Experiments II and III the percent of phosphorus in the meat as a whole is the same in the corn lot and the low-phosphorus lot, but the proportion of phosphorus to protein is greater, and the percent of phosphorus in the ash is greater in the corn lots in both experiments, than in the low-phosphorus lots, because of the smaller amount of protein and of ash in the muscles of the corn-fed pigs. These differences are less in Experiment II, where the sodium phosphate was fed to the low-phosphorus lot, than in Experiment III where the hominy and blood-flour were fed alone. In both experiments the gain in muscle was much greater on the low-phosphorus ration, which was high in protein, than on the corn ration, which was much higher in phosphorus, but lower in protein.

In both Experiments II and III there is quite decidedly less phosphorus in the meat as a whole, in the protein, and in the ash, in the muscles of the bran-extract lots than in the corn lots, in fact these bran-extract lots are lower in the phosphorus in the muscles than any other, without exception, in either experiment, while at the same time these rations caused the greatest increase in the weight of these muscles. (Table XXIII, page 284).

The bone-meal and the low-phosphorus lots in these two experiments furnish a most interesting comparison.

Adding bone-meal to the ration of hominy and blood-flour increased the proportion of ash to protein in the muscles produced; did not increase the percentage of phosphorus, either in the muscle or in the ash of the muscle; and decreased the percentage of protein in the muscles.

In both experiments the undetermined constituents were slightly greater in amount with the bone-meal lot than with the low-phosphorus lot, which, assuming the work to be correct, might indicate a higher percentage of glycogen.

Bran-extract has a tendency to produce muscles containing a low percentage of phosphorus in the ash. In Experiment II, the bran-extract lots were lower than others in this regard, the lot receiving the most bran-extract being the lowest, and in Experiment III the bran-extract lot was again lowest of all. In both experiments the lot having the least phosphorus in the meat had received bran-extract. The rations, however, containing bran-extract were high in phosphorus.

The results from the analysis of the meat samples from the one pig which received lecithin with the basal ration of hominy and blood-flour, and which constituted Lot 3, in Experiment II, are regarded as having greater value than the weights of organs of this pig, and data regarding gains in weight. It would seem from these figures that the lecithin had tended to the production of muscles containing a high moisture content, low percentage of protein and of fat, very high percent of phosphorus, high percent of water in the fat-free meat, high percent of ash, and high proportion of phosphorus to protein, and high percent of phosphorus in the ash.

In the kidneys the lecithin lot contained a low percent of water, and was high in protein and in phosphorus, but the proportion of phosphorus to protein was not unusual. (Table XXVII, page 292).

The liver of this pig analyzed high in phosphorus, and high in the percent of phosphorus in the ash. (Table XXVIII, page 294).

Hence we may say regarding the lecithin lot, that the phosphorus content of the meat as a whole, in the muscles, was much higher than in any other lot; in the liver it was as high as in any lot, and in the kidneys it was exceeded only by the check lot which was not fed. The small amount of lecithin fed has produced these marked effects only because the basal ration to which it was added was exceedingly low in phosphorus compounds.

TABLE XXVII: ANALYSES OF KIDNEYS.
EXPERIMENT II.

Lots	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	78.21	15.78	3.07	1.17	.232	80.69	14.09	1.47	7.41	19.83
2	Hominy; blood-flour; bran-extract, (larger amonnt	80.68	14.34	2.65	1.02	.243	82.88	13.72	1.69	7.11	23.82
3	Hominy; blood-flour; lecithin	78.80	16.38	2.89	1.15	.258	81.15	13.63	1.58	7.02	22.43
4	Hominy; blood-flour; bran-extract, (smaller amount)	79.99	15.62	2.57	1.10	.250	82.10	12.84	1.60	7.04	22.73
5	Hominy; blood-flour; bone-meal	79.27	15.49	2.94	1.11	.205	81.67	14.18	1.32	7.17	18.47
6	Hominy; blood-flour; sodium phosphate	80.55	14.56	2.72	1.12	.234	81.16	13 98	1.61	7.69	20.90
7	Check lot	78.80	16.83	1.99	1.20	.262	80.40	9.38	1.57	7.13	21.83
	EXPERIMENT III										
1	Corn	76.70	17.07	4.95	1.14	.313	80.69	21.24	1.83	6.68	27.46
2	Check lot	80.32	14.37	2.11	1.12	.249	82.05	10.72	1.73	7.79	22.23
3	Hominy; blood-flour; bran-extract	79.78	15.79	3.41	1.11	.249	82.60	16.86	1.58	7.03	22.43
4	Hominy; blood-flour; bone-flour	77.18	16.01	3.92	1.14	.318	80.33	17.18	1.99	7.12	27.90
5	Hominy; blood-flour	77.84	17.00	3.91	1.07	.294	81.01	17.64	1.73	6.29	27.48

The kidneys from the corn-fed pigs, (Table XXVII, page 292), contained less water and more fat, in both Experiments II and III, than from any other lots. In both experiments they were high in protein and in ash. The phosphorus content of the kidneys of the young pigs of Experiment III, was much higher in the corn lot, the the bone-flour lot, and the low-phosphorus lot, but lower in the check lot, than in the corresponding lots of older pigs in Experiment II.

The kidneys of the bran-extract lots were, in both Experiments II and III, lower in fat than any except the check lot; were high in percent of water, and higher than any other lots in percent of water in the fat-free meat; were low in fat in the water-free meat; low in ash, and in proportion of ash to protein.

The bone-meal ration produced kidneys that were high in fat, both on the basis of the whole meat and the water-free meat, and in both Experiments II and III were higher in fat than in the bran-extract, the low-phosphorus, and the check lots.

The livers of the corn-fed lots,(Table XXVIII, page 294), were characterized by only two conditions that hold good through both experiments; in each they are comparatively low in ash and in phosphorus.

The livers of the bran-extract lots are characterized by being high in percent of phosphorus, and high in percent of phosphorus in the ash. Compared with the bone-meal lots, the bran-extract lots, No. 4 in Experiment II, and No. 3 in Experiment III, were the higher in both experiments in water, protein, fat, phosphorus, water in the fat-free meat, fat in the water-free meat, and phosphorus in the ash. The phosphorus and ash in the protein were higher in the bone-meal lots.

Since water, fat and protein were all higher in the livers of the bran-extract lots than in the bone-meal lots, this would indicate a higher glycogen content in the livers of the latter, or errors in analytical work.

The livers of the low-phosphorus lots, No. 6 in Experiment II and No. 5 in Experiment III, were high in percentage of protein and ash, but low in water and phosphorus, and in the proportion of ash and of phosphorus to the protein.

TABLE XXVIII: ANALYSES OF LIVERS.
EXPERIMENT II.

Lots	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn..........	74.24	18.83	2.81	1.27	.320	76.39	10 91	1.70	6.74	25.20
2	Hominy; blood-flour; bran-extract, (larger amount)...........	73.52	17.19	2.46	1.37	.356	75.37	9.29	2.07	7.97	26.00
3	Hominy; blood-flour; lecithin..............	71.98	18 72	2.90	1.29	.364	74.13	10.35	1.94	6.89	28 22
4	Hominy; blood-flour; bran-extract, (smaller amount).................................	71.96	20.13	3.01	1.32	.364	74 19	10.74	1.81	6.56	27.58
5	Hominy; blood-flour; bone-meal........... ..	71.81	19 45	2.65	1 39	.361	73.76	9.40	1.85	7.11	25.97
6	Hominy; blood-flour; sodium phosphate ...	72.05	20.58	2 85	1.34	.324	74.16	10.20	1.57	6.51	24.18
7	Check lot..........................	71.48	14.61	1 84	1.17	.291	72.82	6.45	1.99	8.01	24.87
	EXPERIMENT III										
1	Corn	70.77	16.08	2.32	1.21	.338	72.45	7.94	2.10	7.52	27.93
2	Check lot................................. ..	71.21	18.12	3.01	1.33	.338	73.42	10.46	1.87	7.34	25.41
3	Hominy; blood-flour; bran-extract	71.65	20.44	2.49	1 30	.367	73.48	8.78	1.80	6.36	28.23
4	Hominy; blood-flour; bone-flour	70.43	19.31	2.03	1.30	.366	71.90	6.87	1.90	6.73	28.15
5	Hominy; blood-flour	70.64	20.97	2.26	1.34	.346	72.27	7.70	1.65	6.39	25.82

CONCLUSIONS FROM EXPERIMENTS II AND III.

Experiment II, Lot 1, (corn alone). By reference to Table XIX, page 271, we see that Lot 1 received the lowest proportion of proteid to non-proteid food, the smallest amount of calcium and of sulphur, but more phosphorus, than any lot except Lot 2, (larger amount of bran-extract). The ration contained a greater excess of mineral acid over mineral base than any other.

This ration of corn alone produced the least increase in live weight, (Table XX, page 278), the smallest and weakest bones, (Table XXV, page 288), the smallest percent of liver, kidney and muscle in the increased weight, (Table XXIV, page 285), the smallest gain in the weight of the heart, and the largest increase in the leaf-lard and back-fat, (Table XXIII, page 284).

The weakness of the bones is attributed principally to the deficiency of corn in calcium and in protein, and to the considerable excess of mineral acid over mineral base in this feed. The great excess of magnesium in proportion to calcium is also probably a factor in the inefficiency of corn to produce bone.

The low proportion of proteid tissues and high proportion of fat in the increase is due mostly to the low protein content of this feed; and proteid increase was also doubtless interfered with by the excess of acid mineral elements.

Experiment III, Lot 1, (corn alone). The corn ration, in Experiment III, (Table XIX, page 272), was low in protein and calcium but high in phosphorus in comparison with these other rations. It seemed to be poorly adapted to the production of tissue, the gains in live-weight, muscles and internal organs being generally very low. It was better adapted to the production of fat, of lungs, and of ash in the bones than to other purposes. (Table XXIII, page 284). We should bear in mind, however, that corn is a very poor bone food, and that it excelled in this experiment only because the other rations were still less efficient. The high fat production seems to be due principally to the low proportion of protein in the ration, the animal being forced to make fat through its inability to construct proteid growth from the nutrients provided. The low calcium content of the ration was quite unfavorable to bone formation. The comparative abundance of phosphorus and the deficiency in protein, which limited the use of phosphorus in proteid increase, accounts, in part, for the considerable gain which there was in the ash of the bones, the ash per cubic centimeter of volume being higher than in other lots. (Table XXV, page 288).

In both Experiments II and III the proportions of lungs, leaf-lard and back-fat were all higher in the increase made by the corn ration than with the balanced rations, but the proportions of kidneys and muscles in the increase with the corn ration were lower than with the other rations, which contained more protein.

In Experiment I, (Table XI, page 261), the same relations exist in the development of these organs, between the corn rations and the balanced rations, except that the increase in lungs is comparatively less than in the balanced rations.

The association of small kidneys and muscles, with thick back-fat and heavy leaf-lard, in the lots which received corn alone, is apparently simply the result of the lack of protein in the ration.

The muscular tissue produced from corn was characterized by high fat and low protein contents, and by high water content of the fat-free meat.

The kidneys of the corn-fed pigs were low in water content, and higher in fat than the kidneys from other lots.

The livers of the corn-fed pigs were low in ash and in phosphorus.

The younger pigs used in Experiment III did not thrive on this corn ration nearly so well as did the older pigs of Experiment II.

Experiment II, Lot 2, (hominy, blood-flour and bran-extract, larger amount). This lot which received the larger amount of bran-extract, received about the same organic nutrients as Lot 4, which received a very much smaller amount of bran-extract; hence we may look to differences in the mineral nutrients for explanation of differences in results. The lot which received the larger amount of the extract received in its ration more mineral nutriment than the lot receiving less of this extract, and since the balance of mineral acid to base in bran-extract is in favor of the basic elements, ration No. 2, containing the larger amount of this food, contained a smaller excess of mineral acid over mineral base than than did ration No. 4. These observations are all in favor of Lot 2; but this lot of pigs was constantly in discomfort, and the results show that something was wrong with the ration. The bones of the pigs were less in volume, (Table XXV, page 288); the ash per cubic centimeter of volume of bones was less; the breaking strength of the bones was much less, and the measurements of length and diameter were less where the larger amount of bran-extract was used.

The gain in live weight, heart, lungs, leaf-lard, muscles and back-fat was less, and the gain in liver, spleen and kidneys decidedly greater where the larger amount of the bran-extract was used. (Table XXIII, page 284).

These differences seem to be due to the great excess of magnesium over calcium in bran-extract, which resulted in a withdrawal of calcium from the body; it is possible that the large amount of phytin in the bran-extract also contributed to the unfavorable results, though at least in moderate quantities this compound is a valuable nutrient.

Experiment II, Lot 3, (low-phosphorus basal ration and small amount of lecithin). This lot, which received a small amount of pure lecithin in the feed, was composed of but a single pig, and we hesitate to draw conclusions from results with a single individual; we would call attention, however, to the facts that this ration, differing from that fed to Lot 6 only in that the latter received as sodium phosphate the same amount of phosphorus that the former received as lecithin, produced greater gain in live-weight at a lower expenditure of food and the percent of gain in heart, liver, spleen, leaf-lard and muscles, and in the ash, volume, ash per cubic centimeter of volume and breaking strength of the bones was also greater with this ration containing lecithin.

The gain in the lungs and kidneys was less where lecithin was fed than where the phosphorus was fed as sodium phosphate. These facts may indicate high proportion of storage of the nutrients in the body and, in consequence, low eliminative activity.

These observations, coupled with the more rapid and economical gain in weight, and the greater increase in the growth of muscles, visceral organs and bones, might be considered to indicate that the lecithin had exercised a very favorable influence in the animal economy. These deductions are suggested because, though this evidence is insufficient for their establishment, subsequent work by the author at the Ohio Station sustains these observations. They appear to be in harmony with the facts. It may be well, however, to call attention to the fact that these results were obtained with rations which were very low in phosphorus. We have as yet no evidence to warrant the supposition that any such results would have attended the addition of lecithin to a normal ration, or that lecithin is the only organic phosphorus compound possessing the same capacities. Ten percent of the phosphorus of this low-phosphorus ration was in the shape of lecithin.

The pig selected for this ration was not apparently in any way a superior individual. There was no difference of opinion on this point among those who observed the progress of the experiment.

The muscles of the pig which received lecithin were characterized by a high percent of water and of ash; and of phosphorus, in the tissue as a whole, and also in the ash of the muscle.

The kidneys were low in water content.

The liver, like the muscles, was high in its content of phosphorus, both in the tissue as a whole and in its ash.

Experiment II, Lot 4, (smaller amount of bran-extract) and Lot 5, (bone-meal). Lot 4, which received the smaller amount of bran-extract, gained in weight rapidly and economically, (Table XX, page 278), and there was every evidence that these pigs were well nourished.

The most instructive comparison is between this lot and Lot 5, which received bone-meal with its basal ration. The proportion of protein to non-proteid organic nutrients was the same in both rations. The most marked differences are in the phosphorus compounds used as supplements. In Lot 4 the bran-extract contained a very large amount of phosphorus in an organic combination known as phytin. The ration fed to Lot 5 contained somewhat more phosphorus than the above, but two-thirds of it was inorganic bone phosphate.

This bone-meal ration contained six times as much calcium, but only one-third as much magnesinm, as the bran-extract ration, No. 4, and also contained a smaller excess of mineral acid over mineral base.

Lot 4, which received the organic phosphorus compound from wheat bran, made greater and more economical growth and produced a larger percentage of muscle and fat in the increase, (Table XXIV, page 285), but the development of the bones was very decidedly less, (Table XXV, page 288), being excelled in volume, total ash, ash per cubic centimeter of volume, breaking strength and length, and in one of the two transverse diameters.

The fact that the bone-meal lot received the most calcium and phosphorus explains in part their greater development of bone, but renders still more decisive their failure to develop muscle. Bone-meal seems not to be able, as is bran-extract, to contribute to the development of proteid increase.

The lower potassium content of the bone-meal ration, (Table XIX, page 271), may be a factor in its inferiority for muscle production, since potassium is a prominent constituent of the ash of flesh.

We should also bear in mind that the bone-meal lot ate 14 percent less feed than the bran-extract lot, No. 4, but that at the same time the bones produced were both denser and stronger.

The bone-meal ration contained more than twice as much phosphorus as the low-phosphorus ration, No. 6, but produced a smaller proportion of muscle in the increased weight. This is probably due most largely to the unavailability of the phosphorus of bone for muscle formation, but partially to the lowered digestibility of the protein of this ration because of the presence of phosphorus in this condition. This latter fact has been observed by a number of investigators, among them LeClerc and Cook*.

Experiment III, Lot 3, (bran-extract) and Lot 4, (bone meal). In this experiment the bran-extract ration was consumed in the same amount as the bone-flour ration, and the nutritive ratio and amount of protein were the same. These rations differed, however, as to the amount and kind of ash constituents, the bran-extract ration containing decidedly more potassium and phosphorus but very much less calcium. (Table XIX, page 272).

This excess of calcium in the bone-meal ration increased the amount and proportion of ash in the increase, and the ash per cubic centimeter of volume of bone, but seems not to have been of other conspicuous advantage. (Table XXIV, page 285).

The deficiency of potassium and phosphorus, as compared with the bran-extract ration, is reflected in the gain in live-weight, muscle, heart, liver, spleen, lungs and kidneys. In each case the bran-extract lot exceeded the bone-flour lot. (Table XXIII, page 284). What then did the bone-flour lot do with that amount of nutriment which the bran-extract lot made into the greater amount of protein in the increase? Judging by appearances we would say that they made it into fat, for they looked very much fatter, and in accordance with this idea we find that the leaf-lard was heavier, and the back-fat thicker in this lot. (Table XXI, page 281). There was the same amount of phosphorus in the hominy and blood-flour in both the bran-extract and the bone-flour rations, (Table XIX, page 272), but the phosphorus in the bran-extract was greater in amount than the phosphorus in the bone flour, and was present in a very different compound, in the former case being mostly phytin, and in the latter case being mostly the tri-calcic salt of phosphoric acid.

While this bran-extract produced maximum muscular increase, the muscles were characterized by a lower phosphorus content than is found in any other lot.

The kidneys of the bran-extract pigs were very low in fat, and high in water, both in the tissue as a whole and in the fat-free substance. The kidneys were also low in ash in the tissue as a whole, and also low in proportion of ash to protein.

The livers of this lot were characterized by high contents of phosphorus, both in the tissue as a whole, and in the ash.

* LeClerc and Cook: Journ. Biol. Chem. vol. 2, p. 203.

The addition of bone-meal to the low-phosphorus ration increased the proportion of ash to protein in the muscles produced, by decreasing the percentage of protein. The percentage of phosphorus was not increased either in the muscles, or in the ash of the muscle.

The kidneys were characterized by a high fat content.

Experiment II, Lot 6, ("low-phosphorus lot," basal ration and small amount of sodium phosphate). The "low-phosphorus" ration, No. 6, was also low in calcium, (Table XIX, page 271), but did not contain, as apparently did the corn, and bran-extract rations, an excessive proportion of magnesium to calcium.

There are in the results from this ration no such marked indications that the pigs suffered from a lack of phosphorus as with the same ration in Experiment III, where the pigs were considerably younger, and where no sodium phosphate was fed with the hominy and blood-flour.

The 43.5 grams of phosphorus fed to this low-phosphorus lot as sodium phosphate constituted 10 percent of the total amount of phosphorus in the ration. Its ready solubility may have given it a value out of proportion to its amount, in comparison with the total phosphorus in the ration.

Comparing this low-phosphorus lot, No. 6, with the bran-extract lot, No. 4, we find that the gain in weight was essentially the same, and the efficiency of the two rations to cause gain in weight was the same, (Table XX, page 288). We do see some evidence of the lack of phosphorus, calcium and potassium, in ration No. 6, however, in the smaller gain in the volume and ash of the bones, in their lower breaking strength, (Table XXV, page 288), and in the somewhat smaller proportion of muscle in the increase, (Table XXIV, page 285).

Shotes with well-grown bones and muscles seem to be able to stand a moderate shortage in the ash constituents of the ration for 56 days, without any marked effect. The younger pigs of Experiment III felt the lack of the ash constituents of this ration, the same except for the lack of the sodium phosphate, very much more keenly.

Experiment III, Lot 5, ("low-phosphorus" basal ration). The "low-phosphorus" ration, No. 5, (Table XIX, page 272), consisting of hominy and blood-flour, contained decidedly less calcium, potassium and phosphorus than either the bran-extract or the bone-flour rations. The food was also eaten in smaller amount, but had the same nutritive ratio as these other two. In potassium and phosphorus this ration was much lower than the corn ration, but was decidedly higher in protein and calcium. The greater quantities of calcium and of protein, however, did not compensate for the lack of phosphorus and potassium, for the gain in the ash of the bones was almost nothing; very much less than in the corn lot. (Table XXIII, page 284). The ash per cubic centimeter of volume of the bones was less than with other lots, and was much less than in the check lot, which was not fed. (Table XXV, page 261).

The most interesting conclusion to be drawn from this experiment, however, is that the proportion of muscle in the increase was not greater in the bone-flour lot than in the low-phosphorus lot, No. 5, (Table XXIV, page 285), thus reinforcing our conclusions drawn from Experiment II that the phosphorus of bone is not of appreciable assistance in the formation of muscle. In both these experiments there is a slightly greater proportion of muscle in the increase with the low-phosphorus lot than with the bone-meal or bone-flour lot, but in both cases a less proportion than with the bran-extract lot.

The most noticeable effect of this low-phosphorus ration on the chemical composition of the animal was the low proportion of ash and of phosphorus to protein in the livers.

GENERAL SUMMARY

The limitations imposed by the food supply affect not only the amount, but also, within limits, the composition of the growth produced.

The mineral elements of foodstuffs appear to enter largely into the determination of their specific effects on the development of animals.

Rations of corn balanced by proteid supplements from sources other than corn, appear to be more palatable and more efficient to cause growth than rations of corn and corn products only.

The deficiencies of corn as a food for growing animals appear to be a lack of protein in proportion to non-proteid organic nutrients; a marked lack of calcium, and a less pronounced shortage of phosphorus; an excess of magnesium in proportion to calcium, and a deficiency of basic mineral elements as compared with acid mineral elements.

These deficiencies are all susceptible of correction by the use of supplements. We know of no reason why good sound corn should be entirely withheld from any animal at any time when it needs food.

The specific effects of corn as an only food, as evidenced by the growth of young swine, are in general, a retarded development of proteid and bony tissues, and an over-development of fatty tissue. This results in the production of fine-boned, poorly muscled, undersized and over-fat animals, which reach their limit of growth prematurely, and which are characterized by less than normal breeding capacity. Impaired fecundity seems to result from discouragement of proteid increase generally, and from the lessened circulation of blood in the female reproductive organs, this last being caused by pressure of the excessive amounts of internal fat which accumulate about these parts.

With hogs fed on corn alone, the bones, muscles, liver, kidneys, lungs, heart and spleen all compose an abnormally small proportion of the increase in weight, and fat composes an abnormally large part of the increase.

The muscles of corn-fed pigs are high in fat, and low in protein and in water; but the percentage of water in the fat-free meat is decidedly high. The proportion of ash to protein in the flesh of corn-fed pigs, however, is not low.

The livers of corn-fed hogs are small and low in ash and in phosphorus.

Compared with rations containing more protein, corn produces small, fat kidneys. The low-proteid corn ration makes less extensive requirements, and so produces less development of the kidneys than other rations containing more protein. This has a bearing on the feeding of growing animals. The eliminative functions of the body will not reach full development if the animal be reared on a minimum protein allowance.

The bones likewise are small, and lacking both in density, as indicated by ash content, and in breaking strength.

Corn alone as a food for swine lacks palatability. Hogs will eat very much more of mixed rations, and make much greater, more economical and almost invariably more profitable gains in weight, than from corn alone.

Corn by itself is more nearly a perfect food for maintenance than for growth. The younger the animal, or the greater the amount or proportion of protein in the increase in a given time, the less nearly is corn a perfect food for animals.

In comparing rations of corn alone with rations of corn supplemented with wheat middlings, linseed oil meal, tankage, soy beans and germ oil meal, all rations except the corn being compounded to have the same nutritive ratio, the proteid increase was, in general, in accord with the organic phosphorus content of these rations.

The development of fat was in the inverse order; that is, where the protein of the ration was accompanied by the proper mineral elements, a certain amount of proteid tissue was produced; where the protein of the food lacked the necessary mineral accompaniments, its nitrogenous portion was excreted, and the remainder used for the production of fat and energy. The tankage, linseed oil meal, and soy bean rations were about equally palatable and effective to cause gain in weight.

Tankage and linseed oil meal are about equally profitable supplements to corn at the prevailing prices of recent years.

Soy beans may be grown in the Corn Belt and used with profit in pork production, though the supply of beans on the market is sufficient only to satisfy the demands for seed, at seed prices.

Wheat middlings and germ oil meal are neither so palatable, nor so efficient, nor so profitable, as supplements to corn in pork production as are tankage and linseed oil meal.

The principal organic phosphorus compound of wheat bran, known as phytin, is a valuable nutrient. It contributes to the development of proteid tissues generally, including muscles and visceral organs, and also to the growth of bone.

Phytin was fed as a water-extract of wheat bran, the solution of the phytin being accomplished principally by the slight acidity produced by bacterial fermentation. This bran-extract is characterized by a very high magnesium content, especially so in relation to calcium. The antagonism between these elements in their effect upon the tissues renders this disproportion a matter of importance, since it exists not only in wheat bran and wheat middlings, but also in corn and in other grain feeds.

The excess of magnesium in proportion to calcium in foods appears to cause a counteractive liberation of calcium from the tissues, especially the bones, and thus we may produce malnutrition of the bones merely by the excessive use of a food characterized by disproportionate amounts of magnesium and calcium.

The ash of the bran-extract used in these experiments was, as is the ash of bran, about neutral. Hence this removal of ash from the bones was not acidosis, though the effects upon the bones was the same. Water-extract of wheat bran is a very palatable food. Its nutritive value was most pronounced when used in moderation; the pathological consequences appeared when fed in larger amounts.

"Bran disease," "shorts disease," or "miller's horse rickets" appears to be caused, in part, by the excessive proportion of magnesium to calcium in wheat bran and shorts.

The muscles of pigs which received bran-extract were characterized by a low phosphorus content, though the ration itself was rich in easily assimilable phosphorus.

The livers of pigs which received bran-extract were high in phosphorus, both in the tissue as a whole and in the ash. The kidneys from pigs which received bran-extract were low in fat and in ash, but high in water content.

Lecithin was added to a low-phosphorus basal ration in such quantity as to contribute 10 percent of the total phosphorus of the ration. This ration was compared with another in which the same quantity of phosphorus in the form of sodium phosphate was added to the basal ration.

Lecithin seems to be a valuable nutrient. The ration containing this compound appeared to be especially palatable and excelled in the rapidity and economy of the gain produced.

The muscles, livers and kidneys produced by the lecithin ration all contained a high percentage of phosphorus. Subsequent work by the author at the Ohio Station shows that phosphorus in the same condition as in lecithin contributes to the organic phosphorus content of brain and muscle.

The phosphorus of bone-meal appears not to add to the muscle-producing capacity of a low-phosphorus ration; in fact, there is some evidence to suggest that it interferes, to a slight extent, with the utilization of protein. Bone-meal, however, contributes directly and conspicuously to the ash, density and breaking strength of bone.

Bone-meal does not diminish the tendency of pigs fed on a low-phosphorus ration to make fat from the protein of the food.

The muscles of the pigs which received bone-meal were lower in ash, and percentage of phosphorus in the ash, than the muscles of pigs which had received a low-phosphorus ration lacking the bone-meal.

A ration which was very low in phosphorus, potassium and calcium, but which contained an abundance of protein and other organic nutrients, made very little increase in muscles and in bone ash.

The ration lowest in phosphorus produced muscles which were especially low in water, both in the whole tissues and in the fat-free substance; high in protein, ash and phosphorus, but low in the proportion of phosphorus to protein.

The phosphorus compounds of the food do not directly favor fattening, as they do muscular growth, but they may do so indirectly, through affecting the general health of the animal. On the other hand they are apt to discourage fattening in growing animals through making possible the normal use of the nutriment in the formation of proteid increase.

The general result of this work is to call attention to the importance of the ash constituents generally and to phosphorus in particular in the rations of growing animals.

If we are to use corn as the principal food for animals which are being fed either for growth or production of other proteid increase, such as milk and eggs, we can hope for the greatest success only by feeding with the corn, supplements that are richer in protein, calcium and phosphorus; higher in proportion of basic minerals to acid minerals, and lower in proportion of magnesium to calcium.